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Jaquette et al.

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(54) **MERGING MULTIPLE POINT-IN-TIME COPIES INTO A MERGED POINT-IN-TIME COPY**

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(73) Assignee: **INTERNATIONAL BUSINESS MACHINES CORPORATION**, Armonk, NY (US)

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G06F 16/11 (2019.01)

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CPC *G06F 16/27* (2019.01); *G06F 16/11* (2019.01)

(58) **Field of Classification Search**
CPC G06F 17/30575; G06F 11/1448; G06F 11/1451; G06F 3/0649; G06F 17/3007;
(Continued)

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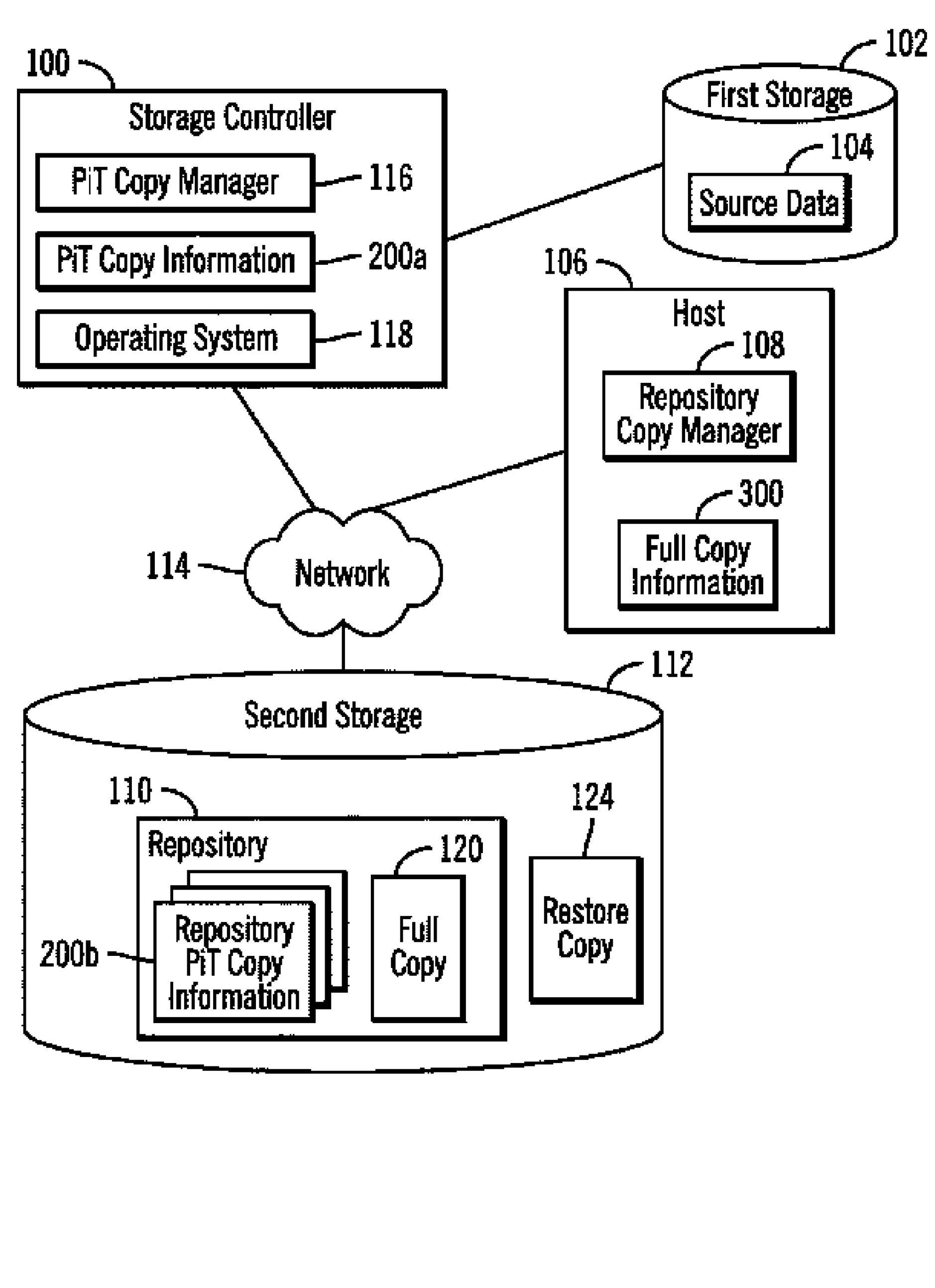
Assistant Examiner — Jedidiah P Ferrer
(74) *Attorney, Agent, or Firm* — David W. Victor; Konrad Raynes Davda & Victor LLP

(57) **ABSTRACT**

Provided are a computer program product, system, and method for merging multiple point-in-time copies into a merged point-in-time copy. A repository maintains a full copy of the source data and point-in-time copies at point-in-times of the source data. Each of the point-in-time copies have change information indicating changed data in the source data that changed between the point-in-time of the point-in-time copy and a subsequent point-in-time and changed point-in-time data comprising data in the source data as of the point-in-time of the point-in-time copy indicated in the change information as changed. At least two selected of the point-in-time copies in the repository are merged into a merged point-in-time copy by: forming merged change information in the merged point-in-time copy indicating changed data indicated in change information for the selected point-in-time copies; and forming merged changed data in the merged point-in-time copy from the changed data in the selected point-in-time copies.

20 Claims, 10 Drawing Sheets



(58) **Field of Classification Search**
CPC G06F 17/30073; G06F 17/30076; G06F 17/30079; G06F 16/113; G06F 16/116; G06F 16/119
See application file for complete search history.

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WO9308529A1 published Apr. 29, 1993, pp. 34, is the English counterpart of CN101149694A.
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Pre-Appeal Brief Request dated Jun. 25, 2018, pp. 6, for U.S. Appl. No. 14/175,975, (18.521).

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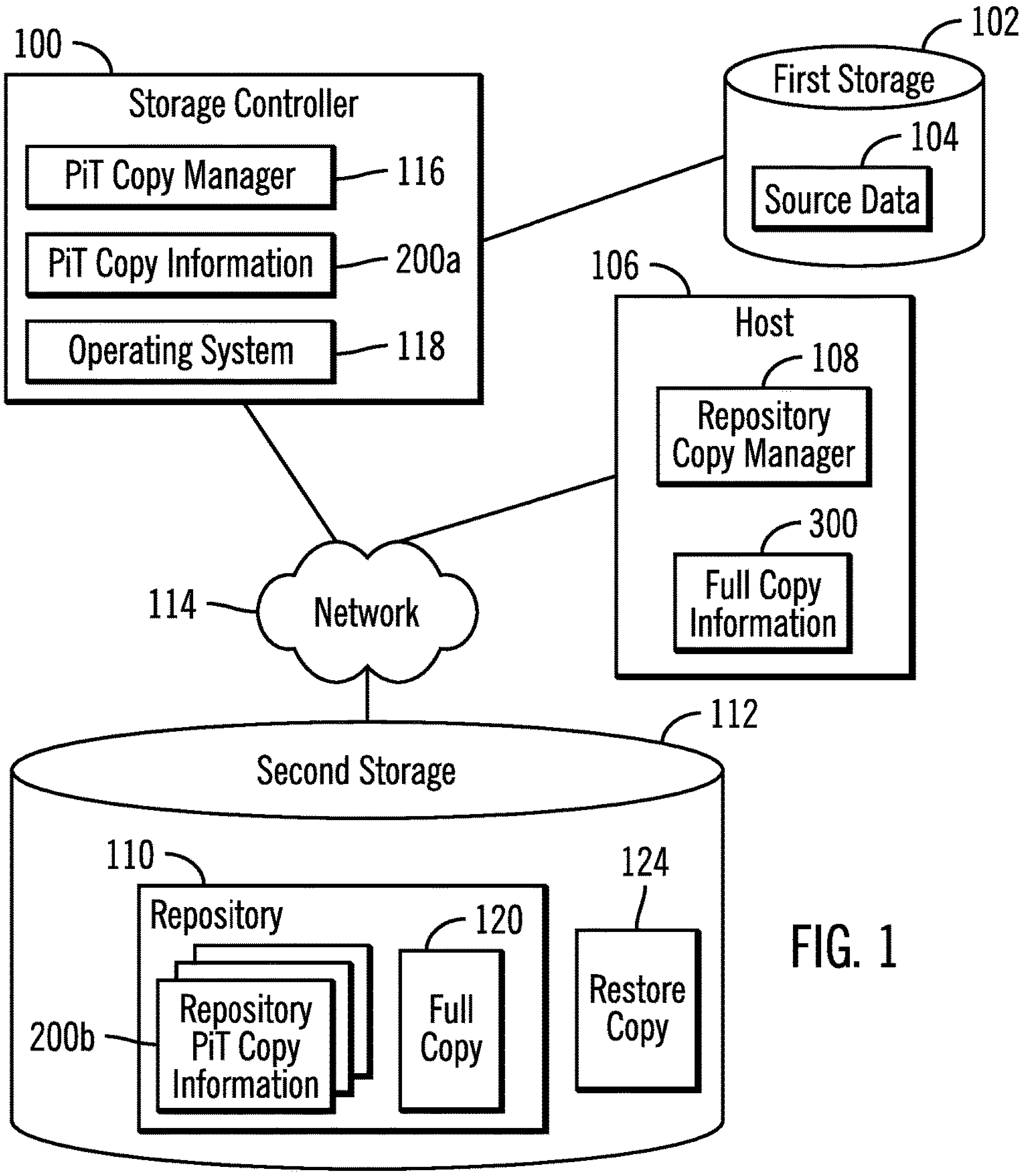


FIG. 1

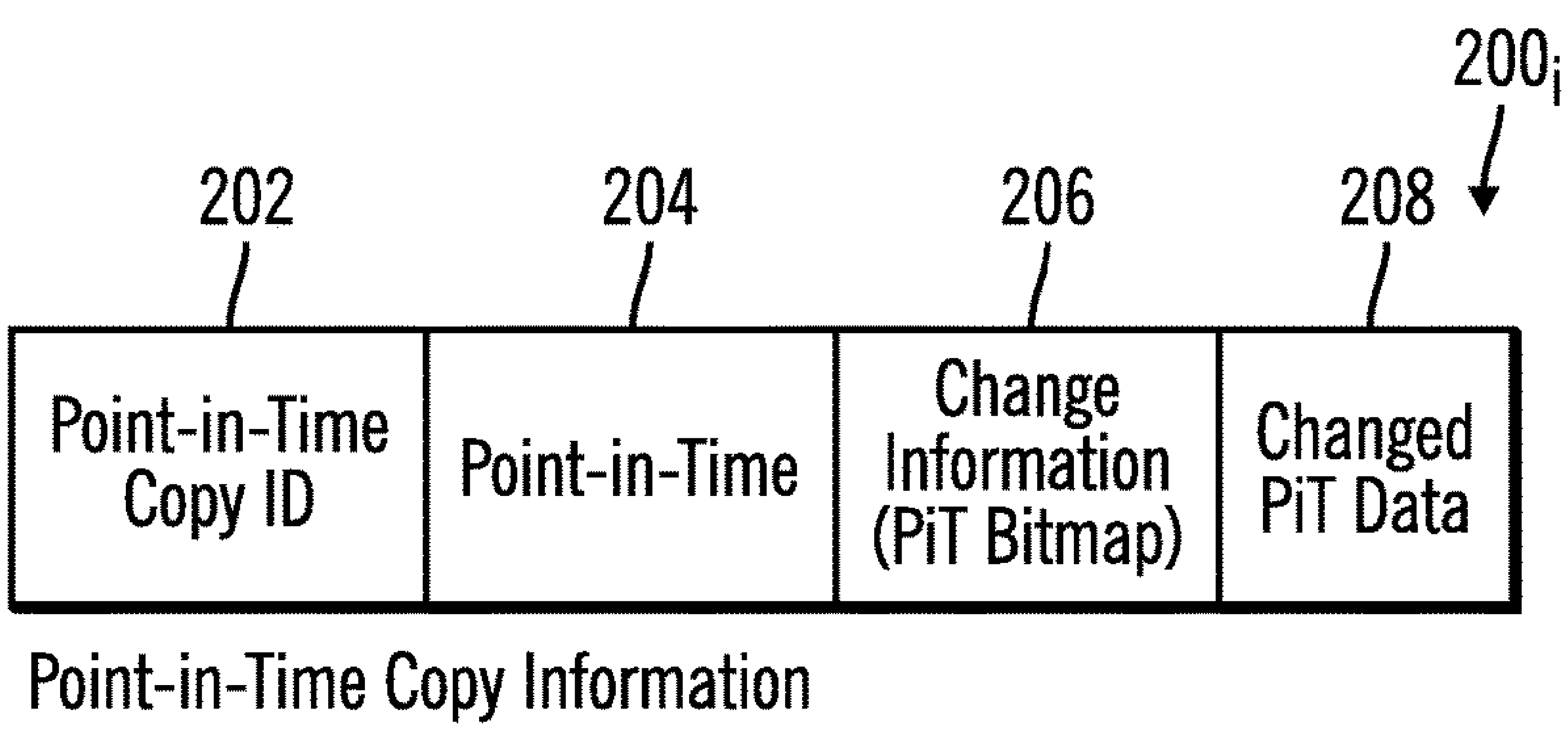


FIG. 2

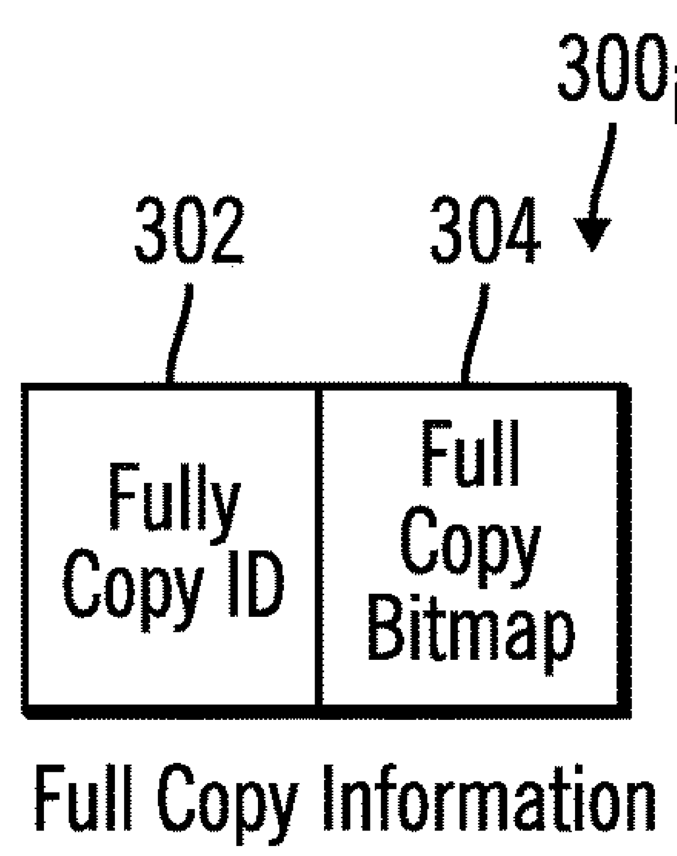


FIG. 3

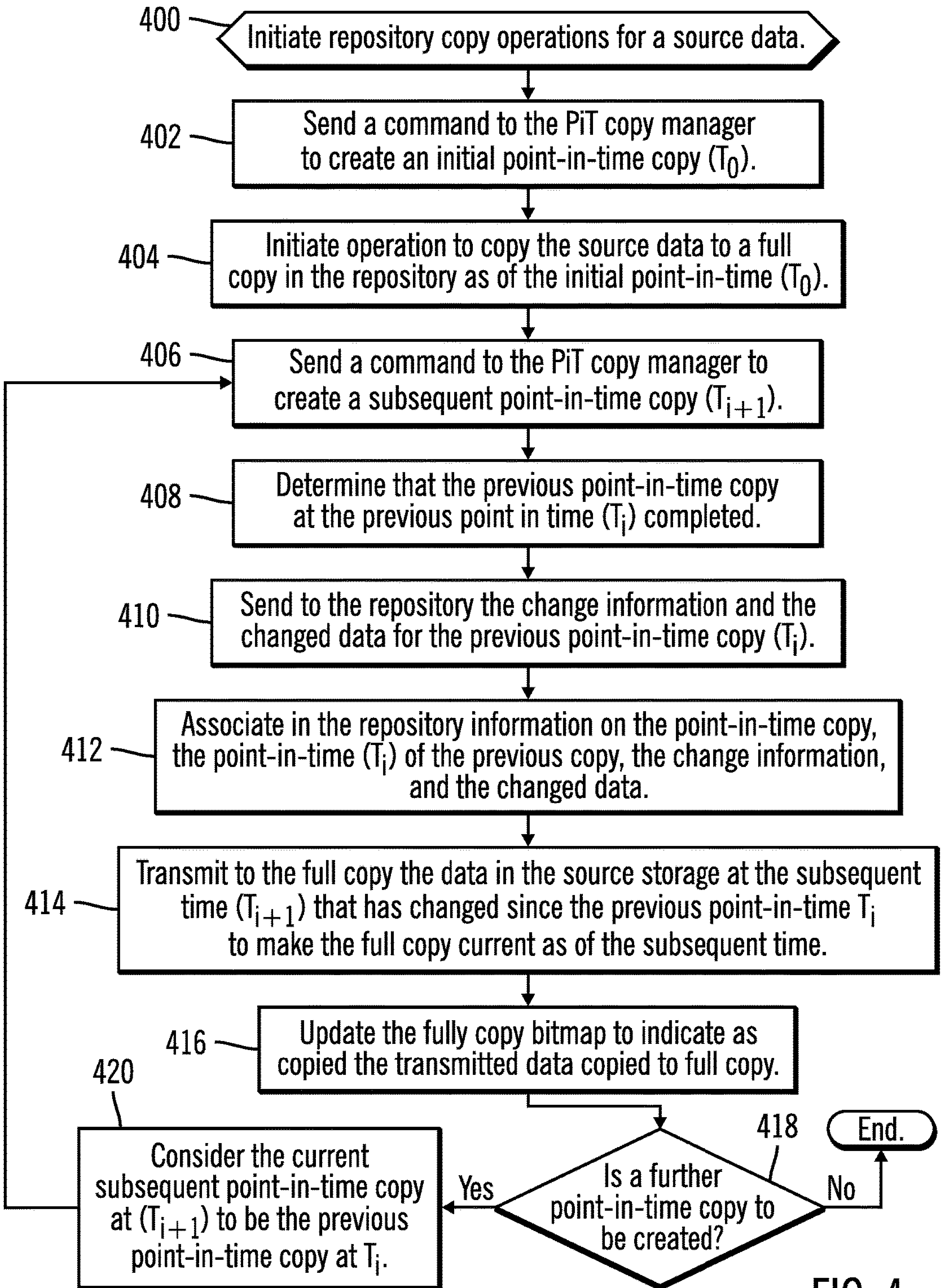

400
Initiate repository copy operations for a source data.
402
Send a command to the PiT copy manager to create an initial point-in-time copy (T_0).
404
Initiate operation to copy the source data to a full copy in the repository as of the initial point-in-time (T_0).
406
Send a command to the PiT copy manager to create a subsequent point-in-time copy (T_{i+1}).
408
Determine that the previous point-in-time copy at the previous point in time (T_i) completed.
410
Send to the repository the change information and the changed data for the previous point-in-time copy (T_i).
412
Associate in the repository information on the point-in-time copy, the point-in-time (T_i) of the previous copy, the change information, and the changed data.
414
Transmit to the full copy the data in the source storage at the subsequent time (T_{i+1}) that has changed since the previous point-in-time T_i to make the full copy current as of the subsequent time.
416
Update the fully copy bitmap to indicate as copied the transmitted data copied to full copy.
418
Is a further point-in-time copy to be created?
No
End.
Yes
420
Consider the current subsequent point-in-time copy at (T_{i+1}) to be the previous point-in-time copy at T_i.

FIG. 4

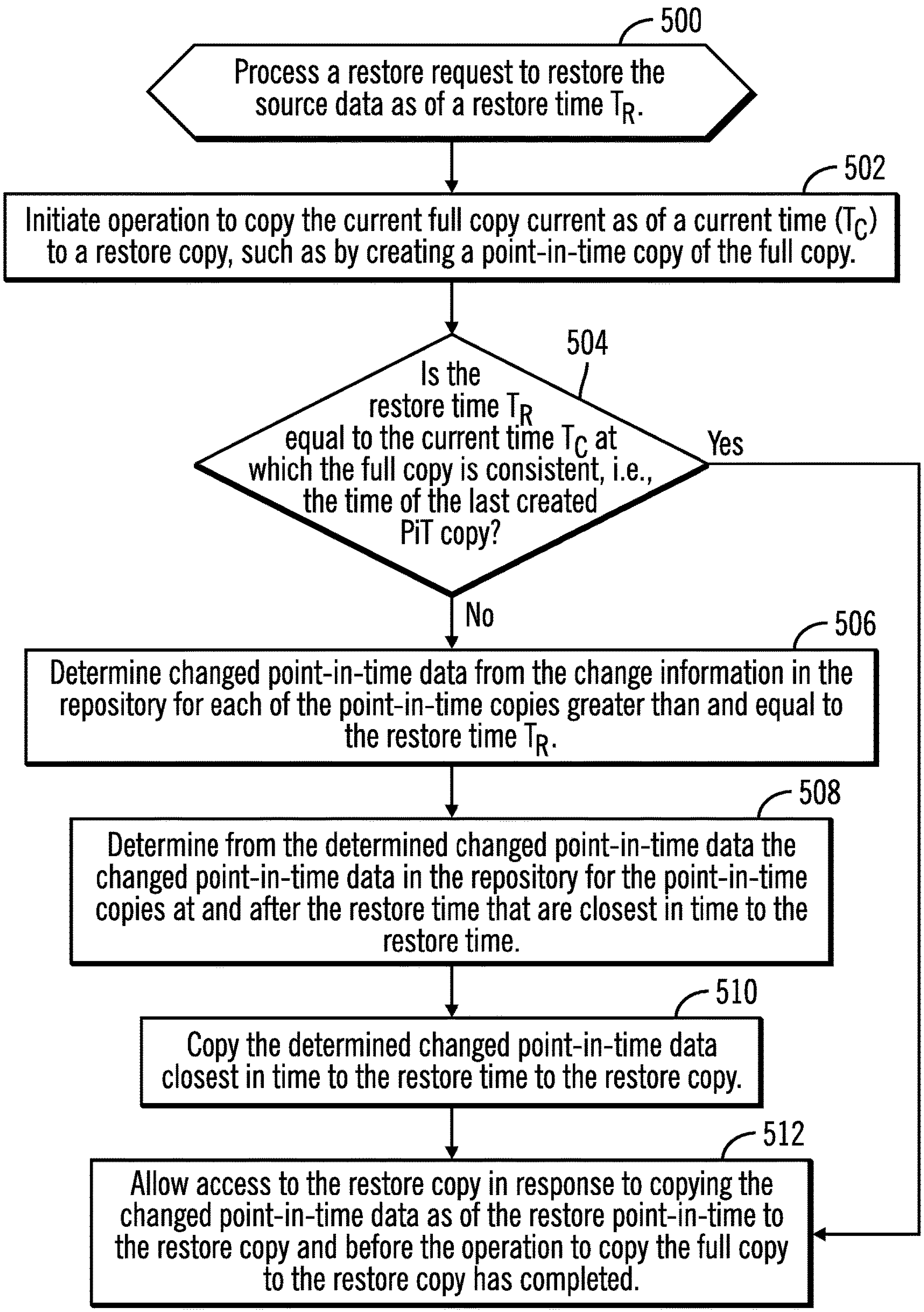
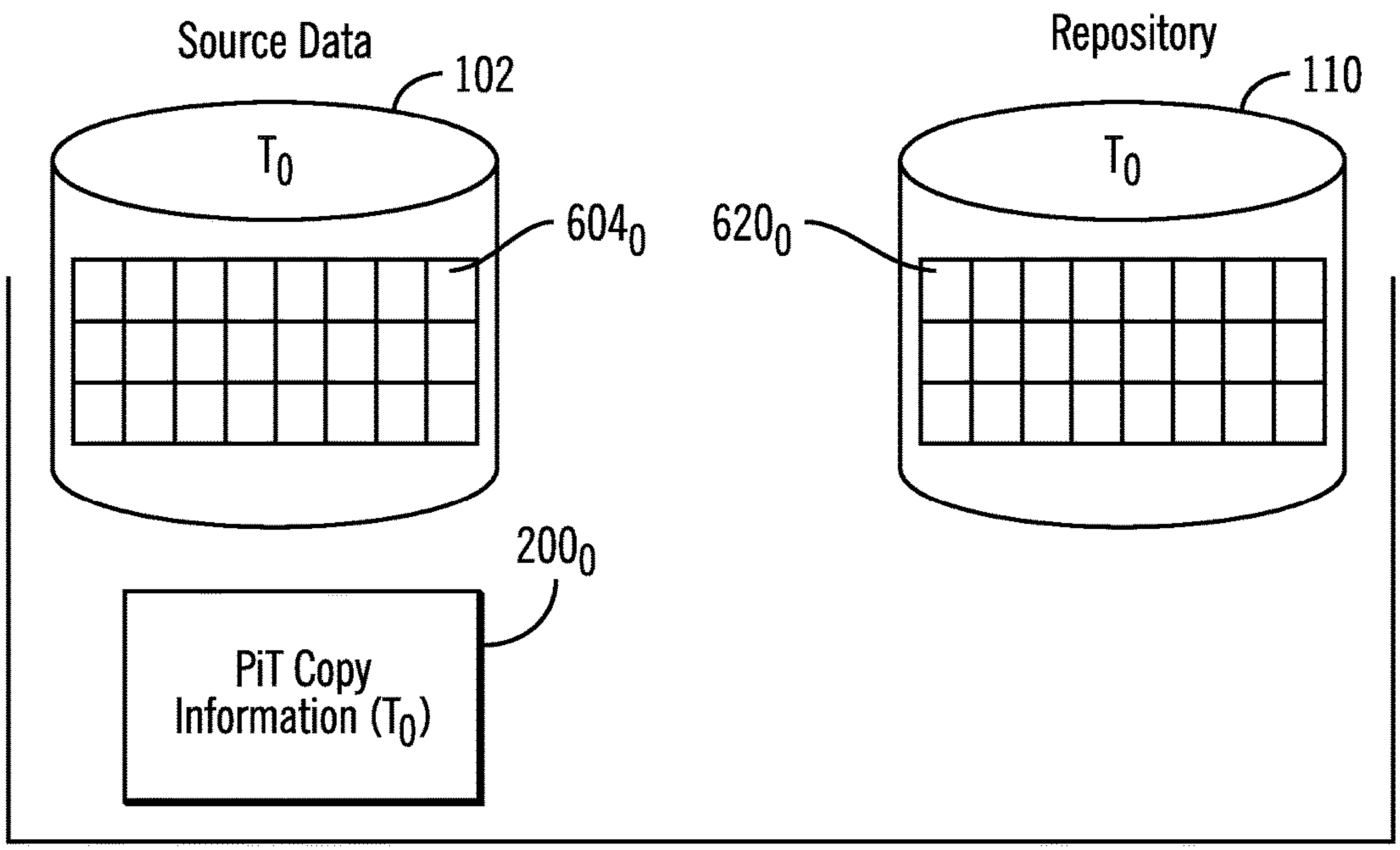
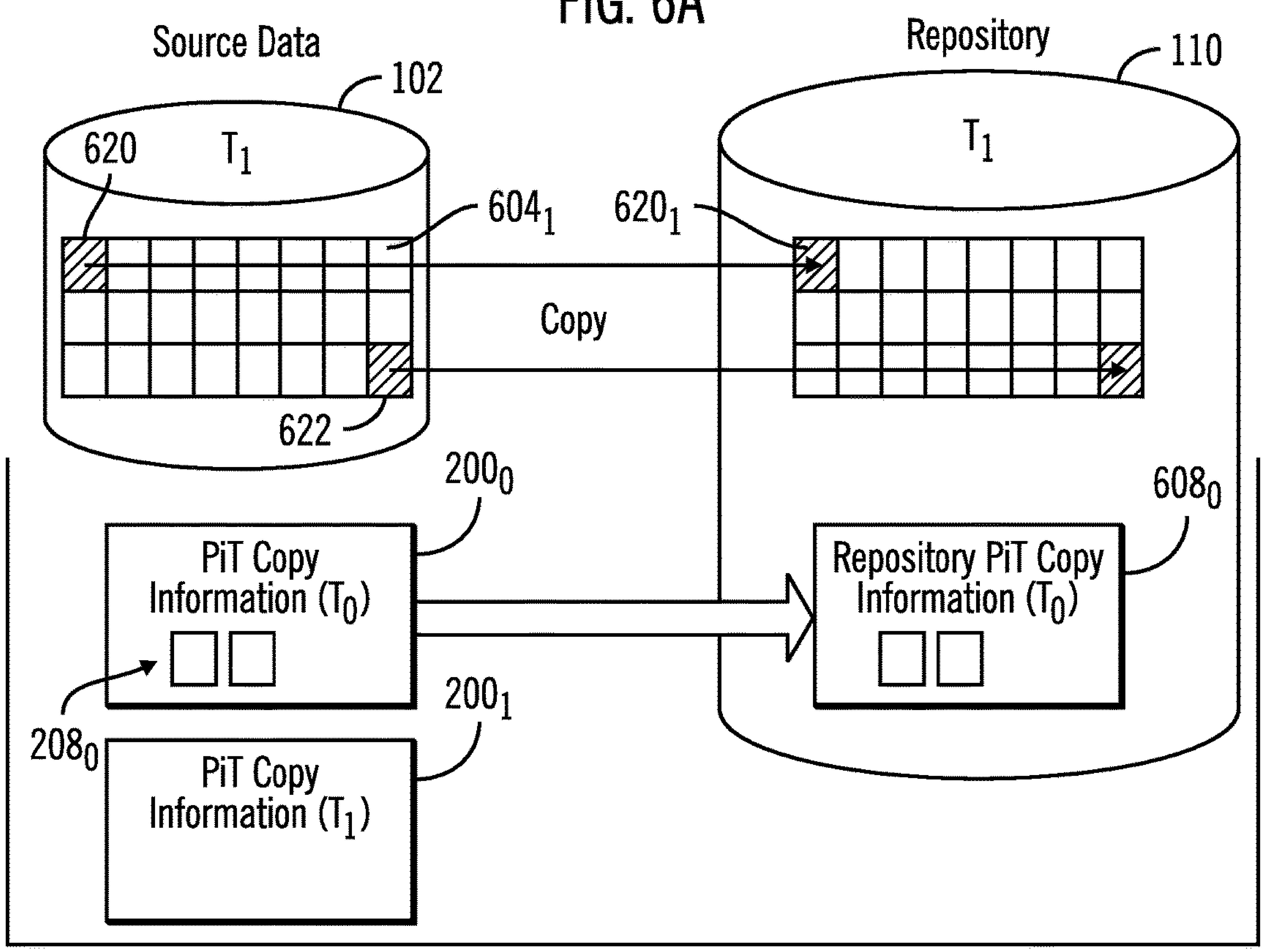

500
Process a restore request to restore the source data as of a restore time T_R.
502
Initiate operation to copy the current full copy current as of a current time (T_C) to a restore copy, such as by creating a point-in-time copy of the full copy.
504
Is the restore time T_R equal to the current time T_C at which the full copy is consistent, i.e., the time of the last created PiT copy?
Yes
No
506
Determine changed point-in-time data from the change information in the repository for each of the point-in-time copies greater than and equal to the restore time T_R.
508
Determine from the determined changed point-in-time data the changed point-in-time data in the repository for the point-in-time copies at and after the restore time that are closest in time to the restore time.
510
Copy the determined changed point-in-time data closest in time to the restore time to the restore copy.
512
Allow access to the restore copy in response to copying the changed point-in-time data as of the restore point-in-time to the restore copy and before the operation to copy the full copy to the restore copy has completed.

FIG. 5



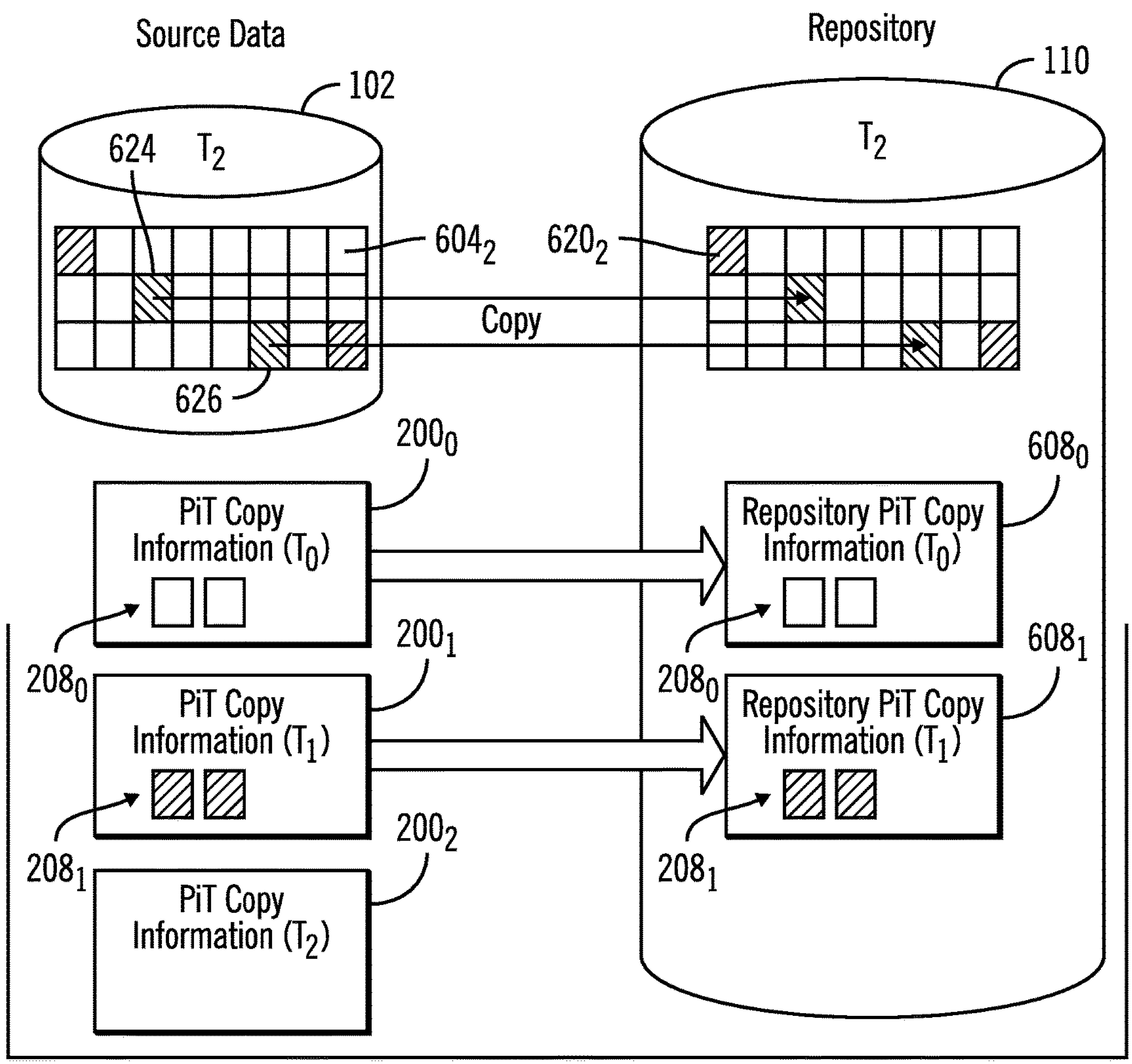
Source Data
102
T0
6040
6200
Repository
110
T0
2000
PiT Copy Information (T0)

FIG. 6A



Source Data
102
620
T1
6041
6201
Repository
110
T1
Copy
622
2000
PiT Copy Information (T0)
2080
2001
PiT Copy Information (T1)
6080
Repository PiT Copy Information (T0)

FIG. 6B



Source Data
102
624
T2
604_2
Copy
626
Repository
110
T2
620_2
200_0
PiT Copy Information (T0)
208_0
200_1
PiT Copy Information (T1)
208_1
200_2
PiT Copy Information (T2)
608_0
Repository PiT Copy Information (T0)
208_0
608_1
Repository PiT Copy Information (T1)
208_1

FIG. 6C

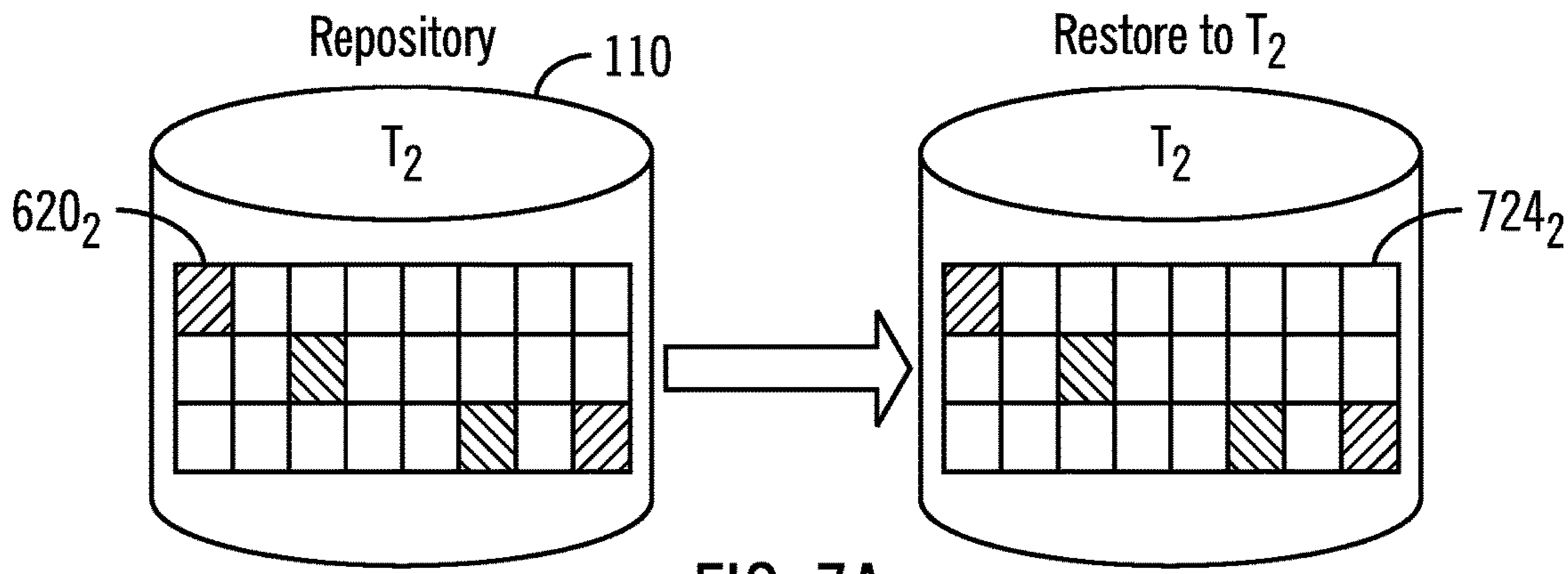


FIG. 7A

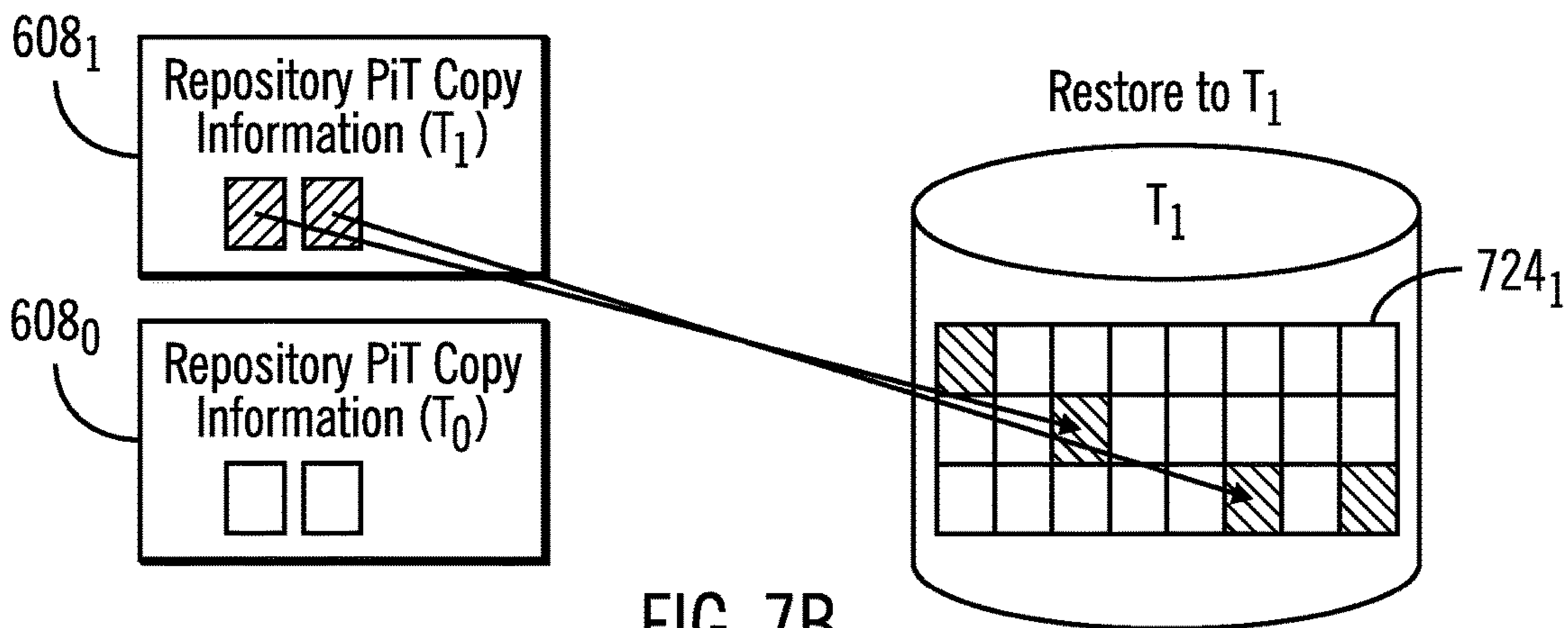


FIG. 7B

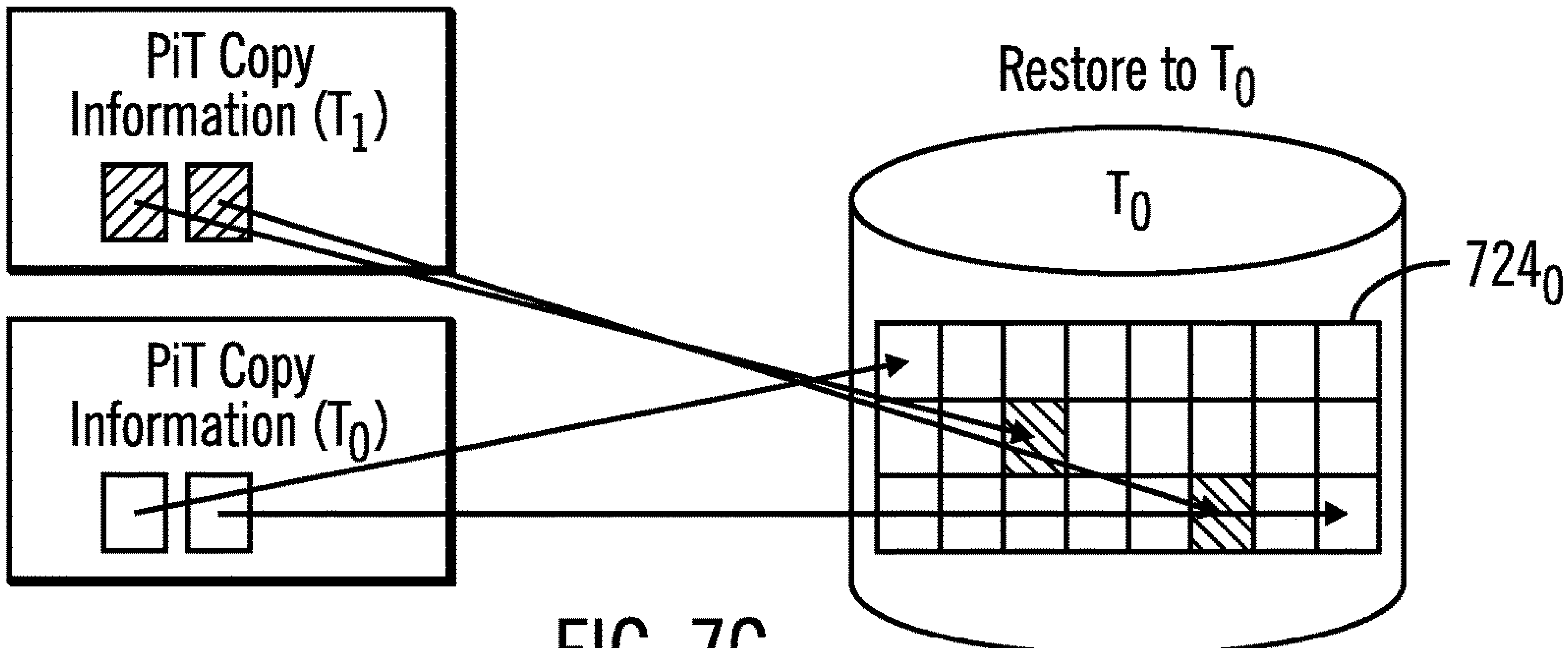


FIG. 7C

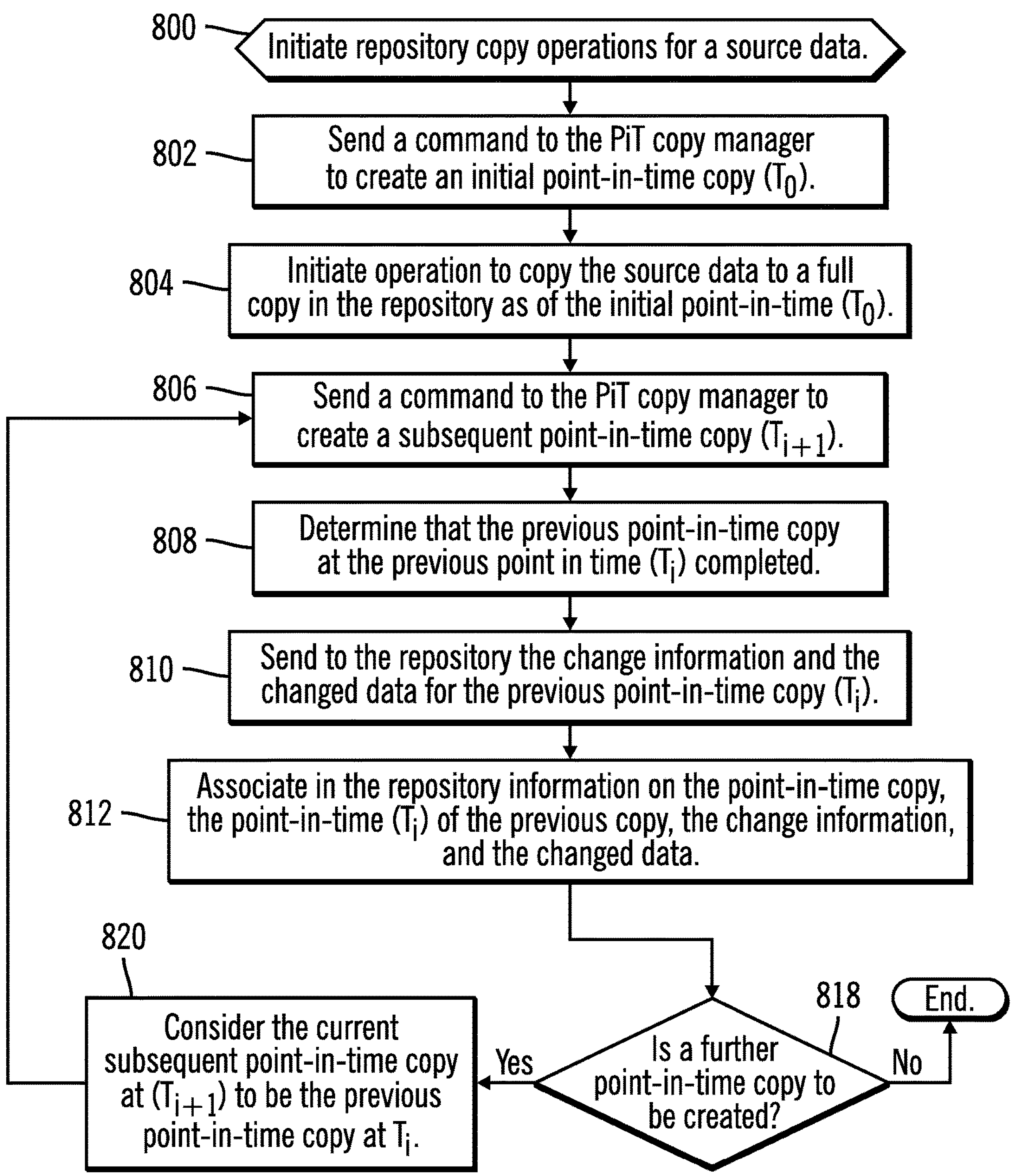

800
Initiate repository copy operations for a source data.
802
Send a command to the PiT copy manager to create an initial point-in-time copy (T_0).
804
Initiate operation to copy the source data to a full copy in the repository as of the initial point-in-time (T_0).
806
Send a command to the PiT copy manager to create a subsequent point-in-time copy (T_{i+1}).
808
Determine that the previous point-in-time copy at the previous point in time (T_i) completed.
810
Send to the repository the change information and the changed data for the previous point-in-time copy (T_i).
812
Associate in the repository information on the point-in-time copy, the point-in-time (T_i) of the previous copy, the change information, and the changed data.
818
Is a further point-in-time copy to be created?
No
End.
Yes
820
Consider the current subsequent point-in-time copy at (T_{i+1}) to be the previous point-in-time copy at T_i.

FIG. 8

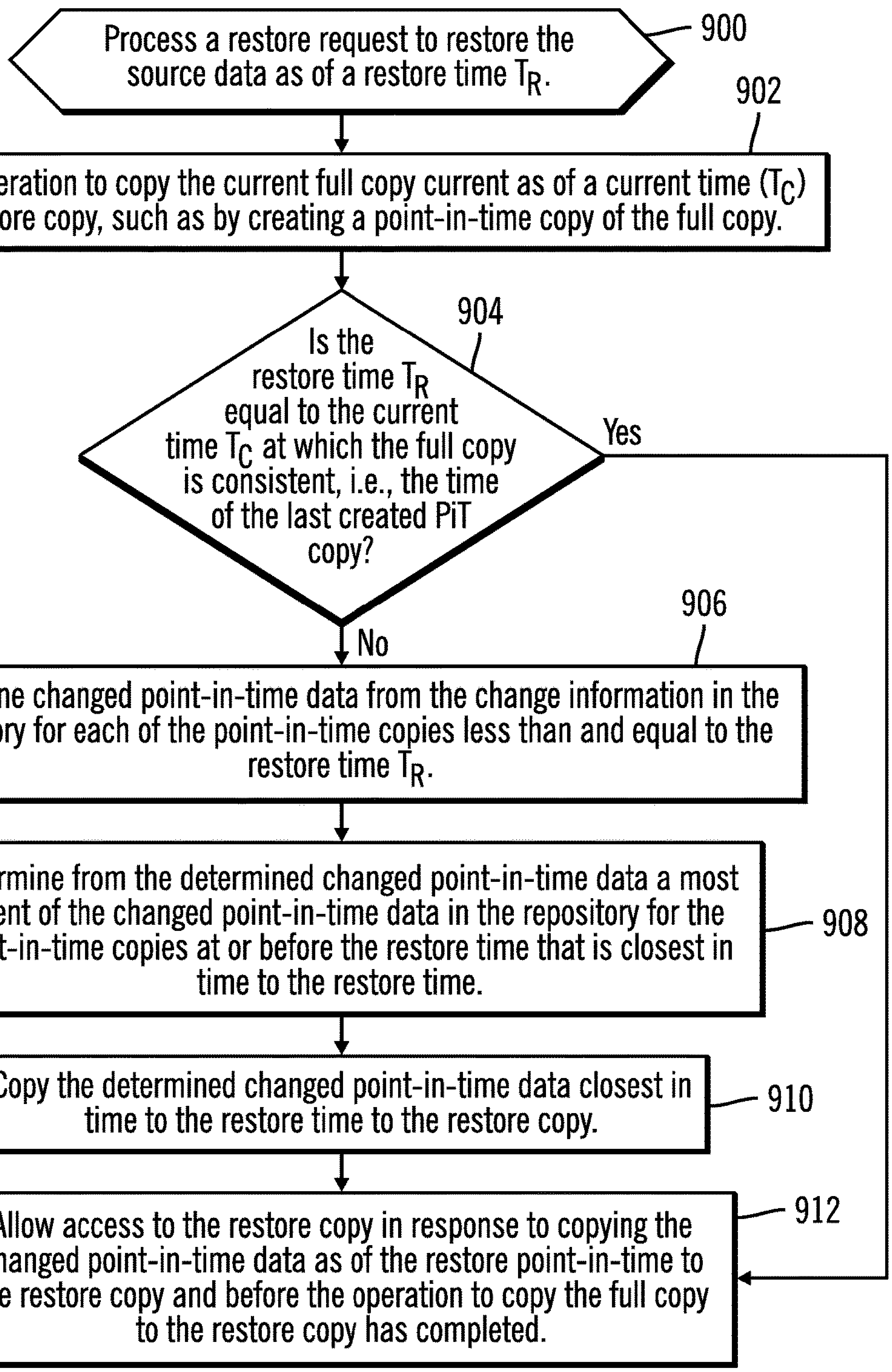
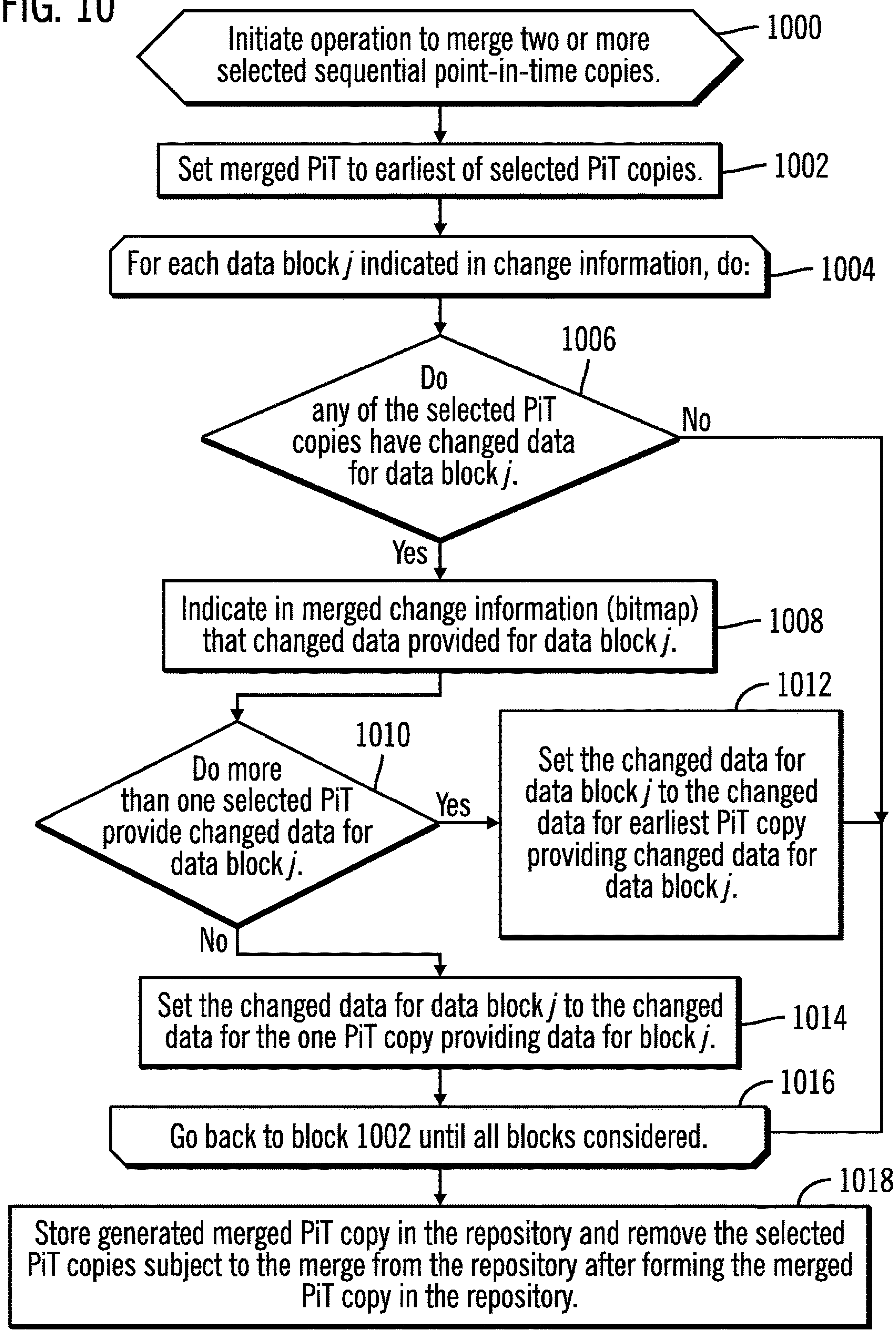

Process a restore request to restore the source data as of a restore time T_R.
900
Initiate operation to copy the current full copy current as of a current time (T_C) to a restore copy, such as by creating a point-in-time copy of the full copy.
902
Is the restore time T_R equal to the current time T_C at which the full copy is consistent, i.e., the time of the last created PiT copy?
904
Yes
No
Determine changed point-in-time data from the change information in the repository for each of the point-in-time copies less than and equal to the restore time T_R.
906
Determine from the determined changed point-in-time data a most recent of the changed point-in-time data in the repository for the point-in-time copies at or before the restore time that is closest in time to the restore time.
908
Copy the determined changed point-in-time data closest in time to the restore time to the restore copy.
910
Allow access to the restore copy in response to copying the changed point-in-time data as of the restore point-in-time to the restore copy and before the operation to copy the full copy to the restore copy has completed.
912

FIG. 9

FIG. 10


Initiate operation to merge two or more selected sequential point-in-time copies.
1000
Set merged PiT to earliest of selected PiT copies.
1002
For each data block j indicated in change information, do:
1004
1006
Do any of the selected PiT copies have changed data for data block j.
No
Yes
Indicate in merged change information (bitmap) that changed data provided for data block j.
1008
1010
Do more than one selected PiT provide changed data for data block j.
Yes
1012
Set the changed data for data block j to the changed data for earliest PiT copy providing changed data for data block j.
No
Set the changed data for data block j to the changed data for the one PiT copy providing data for block j.
1014
1016
Go back to block 1002 until all blocks considered.
1018
Store generated merged PiT copy in the repository and remove the selected PiT copies subject to the merge from the repository after forming the merged PiT copy in the repository.

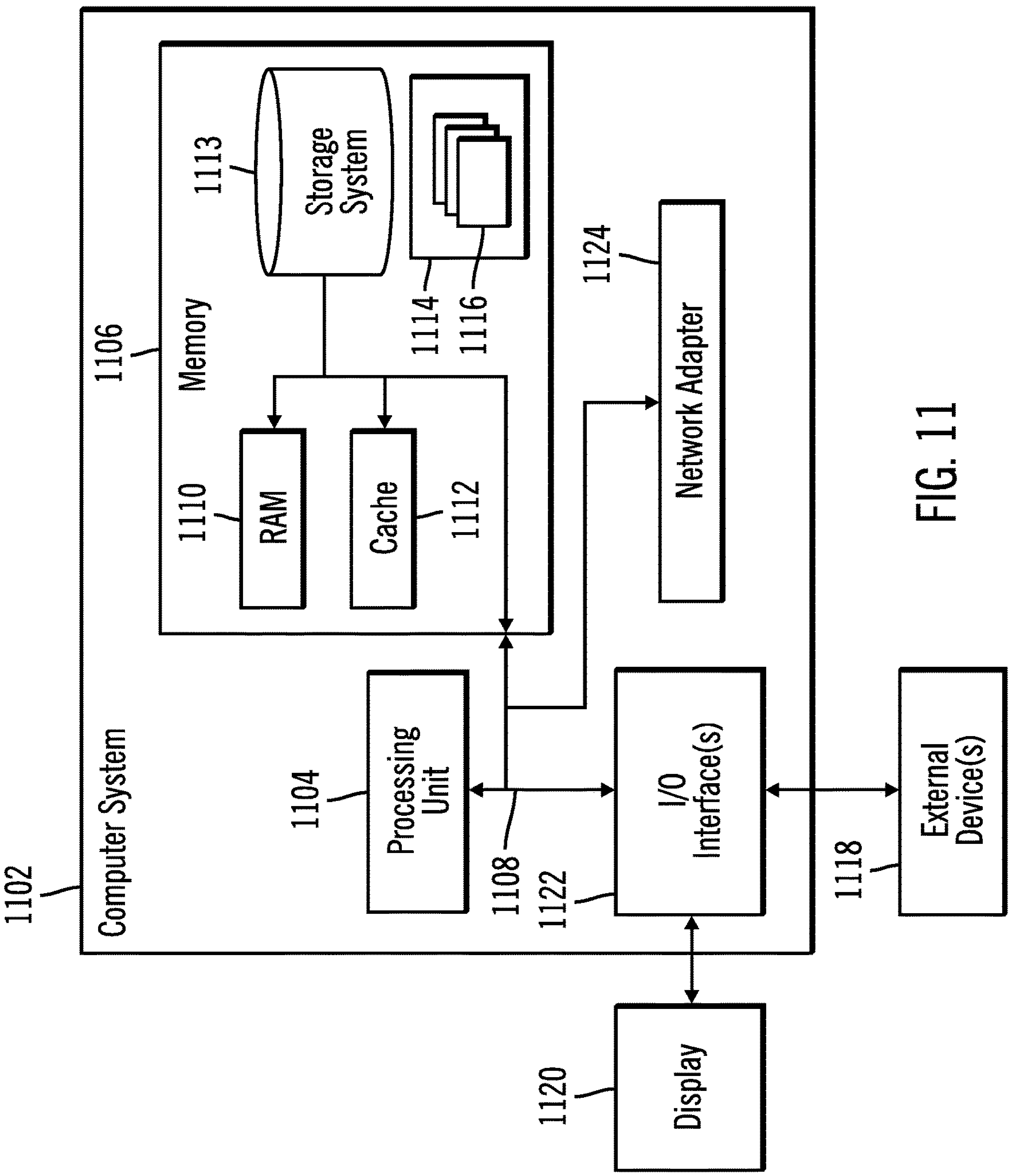

1102
Computer System
1104
Processing Unit
1106
Memory
1110
RAM
1112
Cache
1113
Storage System
1114
1116
1108
1122
I/O Interface(s)
1124
Network Adapter
1118
External Device(s)
1120
Display

FIG. 11

MERGING MULTIPLE POINT-IN-TIME COPIES INTO A MERGED POINT-IN-TIME COPY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a computer program product, system, and method for merging multiple point-in-time copies into a merged point-in-time copy.

2. Description of the Related Art

In a storage environment, a storage controller may create point-in-time ("PiT") copies of a production volume using point-in-time copy techniques, such as the IBM FlashCopy® (FlashCopy is a registered trademark of IBM), snapshot, etc. A point-in-time copy replicates data in a manner that appears instantaneous and allows a host to continue accessing the source volume while actual data transfers to the copy volume are deferred to a later time. The point-in-time copy appears instantaneous because complete is returned to the copy operation in response to generating the relationship data structures without copying the data from the source to the target volumes. Point-in-time copy techniques typically defer the transfer of the data in the source volume at the time the point-in-time copy relationship was established to the copy target volume until a write operation is requested to that data block on the source volume. Data transfers may also proceed as a background copy process with minimal impact on system performance. The point-in-time copy relationships that are immediately established in response to the point-in-time copy command include a bitmap or other data structure indicating the location of blocks in the volume at either the source volume or the copy volume. The point-in-time copy comprises the combination of the data in the source volume and the data to be overwritten by the updates transferred to the target volume.

When an update to a block in the source volume involved in a point-in-time copy relationship is received, the copy of the track as of the point-in-time must be copied to side file or the target volume before the new data for the track is written to the source volume, overwriting the point-in-time copy of the data.

SUMMARY

Provided are a computer program product, system, and method for merging multiple point-in-time copies into a merged point-in-time copy. A repository maintains a full copy of the source data and point-in-time copies at point-in-times of the source data. Each of the point-in-time copies have change information indicating changed data in the source data that changed between the point-in-time of the point-in-time copy and a subsequent point-in-time and changed point-in-time data comprising data in the source data as of the point-in-time of the point-in-time copy indicated in the change information as changed. At least two selected of the point-in-time copies in the repository are merged into a merged point-in-time copy by: forming merged change information in the merged point-in-time copy indicating changed data indicated in change information for the selected point-in-time copies; and forming merged changed data in the merged point-in-time copy from the changed data in the selected point-in-time copies.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an embodiment of a storage environment.

FIG. **2** illustrates an embodiment of point-in-time copy information.

FIG. **3** illustrates an embodiment of full copy information.

FIGS. **4** and **8** illustrate embodiments of operations to create a repository having the source data and point-in-time information of the source data at different point-in-times.

FIGS. **5** and **9** illustrate embodiments of operations to restore a point-in-time copy of the source data from the repository.

FIGS. **6***a*, **6***b*, and **6***c* illustrate examples of states of the source data and the repository at different point-in-times.

FIGS. **7***a*, **7***b*, and **7***c* illustrate the restoration of the source data to different point-in-times.

FIG. **10** illustrates an embodiment of operations to merge point-in-time copies in the repository.

FIG. **11** illustrates a computing environment in which the components of FIG. **1** may be implemented.

DETAILED DESCRIPTION

Described embodiments provide techniques for creating a repository to maintain a full copy of the source data and point-in-time copies of the source data to allow the source data to be restored from the repository at different point-in-times. With described embodiments, multiple selected of the point-in-time copies in the repository may be merged to consolidate the number of stored point-in-time copies. Further, with described embodiments, the operations to maintain the point-in-time copy information in the repository, perform the restore operations, and perform point-in-time copy merge operations may be performed by a program component separate from the storage controller logic creating the point-in-time copies from the source data, so that the repository is separately maintained, used, and managed from the storage controller.

FIG. **1** illustrates an embodiment of a data storage environment having a storage controller **100** managing access to a first storage **102** that includes source data **104**, such as a production volume used by different host systems. A host **106** includes a repository copy manager program **108** to manage the copying of the source data **104** to a repository **110** in a second storage **112**. The storage controller **100**, host **106**, and second storage **112** may communicate over a network **114**.

The storage controller **100** includes a point-in-time ("PiT") copy manager **116** to create point-in-time copies of the source data **104**, e.g., FlashCopy, snapshot, etc. When creating a PiT copy, the PiT copy manager **116** generates PiT copy information **200***a* on the PiT copy created as of a point-in-time. The storage controller **100** further includes an operating system **118**, including the code and logic to manage Input/Output ("I/O") requests to the source data **104**. The operating system **118** may configure the source data **104** in one or more volumes and data is stored in data units, such as tracks, logical block addresses (LBAs), extents, etc. The PiT copy manager **116** may be a copy service supplied with the operating system **118**.

The storages **102** and **112** may store tracks in a Redundant Array of Independent Disks (RAID) configuration where strides of tracks are written across multiple storage devices comprising the storages **102** and **112**. The storages **102** and **112** may each comprise one or more storage devices known in the art, such as interconnected storage devices, where the storage devices may comprise hard disk drives, solid state storage device (SSD) comprised of solid state electronics, such as a EEPROM (Electrically Erasable Programmable Read-Only Memory), flash memory, flash disk, Random

Access Memory (RAM) drive, storage-class memory (SCM), etc., magnetic storage disk, optical disk, tape, etc.

The network **114** may comprise a network such as one or more interconnected Local Area Networks (LAN), Storage Area Networks (SAN), Wide Area Network (WAN), peer-to-peer network, wireless network, etc.

The PiT copy manager **116** performs a PiT copy operation that replicates data in a manner that appears instantaneous and allows a process to continue accessing the source volume while actual data transfers to the copy volume are deferred to a later time. The point-in-time copy appears instantaneous because complete is returned to the copy operation in response to generating the relationship data structures without copying the data.

The repository copy manager **108** may create a full copy **120** of the source data **104** in the repository **110** and copies the PiT copy information **200***a* at the storage controller **100** to the repository **110** to store as repository PiT copy information **200***b* in the repository **110**. The repository copy manager **108** maintains full copy information **300** that is used to manage the creation of the full copy **120**. In this way, the repository copy manager **108** maintains a separate full copy of the source data **104** and the PiT copy information **200***b* of the source data **104** in a separate storage **112** so that data can be restored to different point-in-times independently of the source data **104** in the first storage **102** and the PiT copy information **200***a* at the storage controller **100**. Thus, the repository **110** by allowing for independent restore of the source data **104** provides a redundant secure backup independent of the storage controller **100** to protect from failure at the storage controller **100** or first storage **102**.

In certain embodiments, the creation and management of the repository **110** is managed by a repository copy manager **108** that is separate from the storage controller **100** programs, such as the PiT copy manager **116** that creates the PiT copies. The repository copy manager **108** may use the repository PiT copy information **200***b* and the full copy **120** to create a restore copy **124** at different point-in-times. The full copy **120**, which includes the data as of a most current point-in-time, may be overwritten with data from the repository PiT copy information **200***b* during a restore to roll the database back to a restore point-in-time that may be prior to a current point-in-time of the full copy **120**.

In an alternative embodiment, the repository copy manager **108**, full copy information **300**, and/or the repository **110** may be maintained on the storage controller **100**.

FIG. **2** illustrates an instance of the PiT copy information **200**$_i$ which may comprise information maintained for the storage controller PiT copy information **200***a* and the repository PiT copy information **200***b*. The PiT copy information **200**$_i$ for the storage controller **200***a* and repository **200***b* may be stored in different formats reflecting the different use of that information because the repository PiT copy information **200***b* is intended for use by the repository copy manager **108** to manage the source data in the repository. A PiT copy information instance **200**$_i$ may include a PiT copy identifier **202** identifying the PiT copy created by the PiT copy manager **116** at the storage controller **100**; a point-in-time **204** of the PiT copy **202**, which may mean that data is consistent as of that point-in-time **204**; change information **206** indicating which data or tracks in the source data **104** has changed since the point-in-time **204** and while the PiT copy **202** was open, which may comprise a bitmap having a bit for each data unit (e.g., track) that is set to one of two values indicating the data or track represented by the bit has or has not been updated since the point-in-time **204**; and the changed PiT data **208** comprising the data at the point-in-time **204** that was changed after the point-in-time **204** while the PiT copy **202** was open and still being updated.

In one embodiment, the PiT copy may be completed or frozen at a time subsequent to the point-in-time **204**, such that the changed PiT data **208** includes data changed from the point-in-time **204** until the PiT copy **202** was completed, e.g., frozen or a new PiT copy initiated, and does not include changed data after the PiT copy **202** was completed, e.g., frozen. A PiT copy **202** may be completed upon a freeze command or initiating a subsequent PiT copy at a subsequent point-in-time to the point-in-time **204**. A completed PiT copy **202** may be consistent as of the point-in-time. Other techniques may be used to complete, e.g., freeze, the PiT copy.

In one embodiment, the full copy **120** may be a separate copy of the source data as shown in FIG. **1**. In an alternative embodiment, the data in the full copy **120** may be included in the changed PiT data **208**.

FIG. **3** illustrates an embodiment of full copy information **300**, maintained by the repository copy manager **108**, comprising an instance of the full copy information **300** for one full copy **120** being created in the repository **110**. The full copy information instance **300**, may include a full copy identifier **302** of the particular full copy **120** and a full copy bitmap **304** having a bit for each track or data unit in the source data **104** to copy to the full copy **120**, where each bit indicates whether the corresponding data unit has or has not been copied. The background copy operation of the source data **104** to the full copy **120** is completed after all the bits in the full copy bitmap **304** are set to indicate the source data was copied.

FIG. **4** illustrates an embodiment of operations performed by the repository copy manager **108** and the PiT copy manager **116** to create a repository **110** copy at different points-in-time from the PiT copies for source data **104**, such as a production volume, created by the PiT copy manager **116**. Upon initiating (at block **400**) repository copy operations for source data **104**, the repository copy manager **108** sends (at block **402**) a command to the PiT copy manager **116** to create an initial point-in-time copy **200**$_0$ at an initial point-in-time, referred to herein as T_0. The repository copy manager **108** initiates (at block **404**) an operation to copy the source data **104** to a full copy **120** in the repository **110** as of the initial point-in-time (T_0). A part of the operation to create the full copy **120**, the repository copy manager **108** may initialize full copy information instance **300**$_i$ for the full copy **120** being created, and may initialize all the bits in the full copy bitmap **304** to indicate the corresponding data units in the source data **104** have not been copied. The source data **104** may be copied in the background to the full copy **120** and the full copy bitmap **304** updated for data units from the source data **104** copied to the full copy **102**.

The repository copy manager **108** may send (at block **406**) a command to the PiT copy manager **116** to create a subsequent PiT copy (T_{i+1}) at a subsequent point-in-time T_{i+1}, which would result in PiT copy information **200**$_{i+1}$. In one embodiment, the repository copy manager **108** may send individual commands to the PiT copy manager **116** to create PiT copies and freeze a previously created PiT copy. In an alternative embodiment, the repository copy manager **108** may send one command to the PiT copy manager **116** to instruct it to periodically create PiT copies of the source data **104**, where the creation of a subsequent PiT copy freezes the previously created PiT copy. Still further, the PiT copy manager **116** at the storage controller **100** may be independently creating PiT copies without prompting from the repository copy manager **108**.

Upon determining (at block **408**) that the previous point-in-time copy at T_i completed, the repository copy manager **116** sends (at block **410**) to the repository **110** for storage the PiT copy information **200**$_i$ for the PiT copy at time T_i, including the change information **206** and the changed PiT data **208** to store in the repository PiT copy information for T_i. In one embodiment, a PiT copy at point-in-time T_i may be completed upon the creation of the subsequent PiT copy at time T_{i+1}. In an alternative embodiment, a PiT copy may be completed by issuing a freeze command to freeze the PiT copy so that the change information **206** stops indicating changes to the source data **104**. The repository **110** creates (at bock **412**) in the repository PiT copy information **200***b* an association of the point-in-time **204** of the previous PiT copy, the change information **206** and the changed PiT data **208** for the previous PiT copy.

The repository copy manager **108** may transmit (at block **414**) to the full copy **120** the data in the source data **104** at the subsequent time (T_{i+1}) to make the full copy current as of the subsequent time T_{i+1}. To perform this operation, the repository copy manager **108** may determine from the change information **206** for the previous PiT copy at T_i the data units in the source data **104** that have changed and then copy those data units from the source data **104** to the full copy **120**. In this way, at the subsequent point-in-time T_{i+1} when the subsequent PiT copy (T_{i+1}) is created, data units in the source data **104** that have changed between the previous point-in-time T_i and the subsequent point-in-time T_{i+1} are copied to the full copy **120** in the repository **110**. The full copy bitmap **304** is updated (at block **416**) to indicate any data units from the source data **104** copied to the full copy **120** after the data units are transmitted at block **414**. In this way, the full copy **120** is always moving forward in time, having data current as of the most recent or subsequent PiT copy. At some point, the full copy **120** may be completed while PiT copies are still being created. In such case, the full copy **120** will continue to be updated with changed data units determined at subsequent point-in-times for subsequent PiTs.

If (at block **418**) further point-in-time copies are to be created, then the repository copy manager **108** considers (at block **420**) the current subsequent point-in-time copy at (T_{i+1}) to be the previous point-in-time copy at T_i during the next iteration of processing the next PiT copy. In this way, i is effectively incremented as the current subsequent point-in-time T_{i+1} becomes the previous point-in-time and a next point-in-time becomes the new subsequent point-in-time. Control then proceeds back to block **406** to create or process a new subsequent PiT copy (T_{i+1}) at a new subsequent point-in-time T_{i+1}. If (at block **418**) there are no further PiT copies to process, then control ends.

With the described embodiments of FIG. **4**, a repository **110** of a full copy of the source data **104** having PiT copy information for different PiT copies is created independently of the storage controller operations to create the PiT copies. In this way, the logic or operations of the repository management operations are independent of the storage controller **100** logic to create PiT copies.

FIG. **5** illustrates an embodiment of operations performed by the repository copy manager **108** to restore the source data from the repository **110** to a restore copy **124** at a restore time T_R, where T_R may comprise one of the point-in-times **204** of any repository PiT copy **200***b*. Upon processing (at block **500**) a restore request to restore the source data **104** as of a restore time T_R, the repository copy manager **108** initiates (at block **502**) an operation to copy the current full copy **120** current as of a current time (T_C) to a separate restore copy **124**. In one embodiment, the repository copy manager **108** may invoke the PiT copy manager **116** to create a PiT copy of the full copy **120** and then perform a background copy operation of the full copy **120** to the restore copy **124**. If (at block **504**) the restore time T_R is equal to the current time T_C of the full copy **120** being copied to the restore copy **124**, then the restore copy **124** is complete and access may be allowed (at block **512**) to the restore copy **124**. In one embodiment, the restore copy **124** may be created as a PiT copy of the full copy **120** with a background copy operation to copy the full copy **120** data to the restore copy **124**.

If (at block **504**) the restore time T_R is at a point-in-time earlier than the current time T_C of the full copy **120**, then control proceeds to block **506** to roll back the restore copy **124** created from the full copy **120** to the earlier restore time T_R. At block **506**, the repository copy manager **108** determines changed PiT data **208** from the change information **206** for each of the PiT copies **200**$_i$ having a point-in-time greater than and equal to the restore time T_R. A determination is then made (at block **508**) from the determined changed point-in-time data the changed point-in-time data that is closest in time to the restore time T_R in the repository **110** for PiT copies **200***b* greater than or equal to the restore point-in-time T_R. The determined of the changed PiT data closest in time to the restore time T_R is copied (at block **510**) to the restore copy **124** to roll the restore copy **124** back to the time of the restore time T_R. The repository copy manager **108** allows (at block **512**) access to the restore copy **124** in response to copying the changed point-in-time data as of the restore time (T_R) to the restore copy **124** and before the background operation to copy the full copy to the restore copy has completed. If the user attempts to access data in the restore copy **124** not yet copied from the full copy **120**, then the requested data may be retrieved from the full copy **120** to copy to the restore copy **124** and returned to the user.

In one embodiment, the repository copy manager **108** may consolidate the changed data in the PiT copies greater than or equal to the restore time T_R so that if there are multiple instances of changed data for one data unit at different point-in-times greater than or equal to the restore time T_R then only the changed data for the data unit from the PiT copies closest in time to the restore time is copied to the restore copy **124**. In an alternative embodiment, the repository copy manager **108** may perform a brute force copy method by starting from the most recent PiT copy following the restore time T_R and copying the changed data, and then copying the changed data for each subsequently PiT copy closer in time to the restore time until the changed data for the PiT copy having a point-in-time at the restore time T_R is copied to the restore copy **124**. Other techniques may be used to roll back the restore copy **120** to the restore time prior to the current time.

With the described embodiments, the logic to restore the source data **104** is independent of the storage controller **100** and performed from a repository **110** maintained in a storage system **112** separate from the storage system **102** having the source data **104**. Further, with described embodiments, restore copies may be created and available for use and modification by users without affecting or changing the source data maintained in the repository **110**, which may be used to restore the source data **104** to different point-in-times independent of the storage controller **100** PiT copy manager **116**.

FIGS. **6***a*, **6***b*, **6***c* illustrate an example of the operations of FIG. **4** to create the full copy **120** and repository PiT copy information **200***b*. FIG. **6***a* shows the state at an initial time

T_0 of the source data 604_0 in the source storage **102** that is copied to a full copy **620** in the repository **110**. Further, a PiT copy $\mathbf{200}_0$ is created at the initial time T_0 to capture the source data at the initial time T_0 that is changed following the initial time and store as changed data **208** at the storage controller **100**.

FIG. **6***b* shows a time T_1 when a second PiT copy at T_1 $\mathbf{200}_1$ is created, which may result in the completion or freezing of the PiT copy at T_0 having changed data $\mathbf{208}_0$ as of the point-in-time T_0 before changes occurring between T_0 and T_1. The repository copy manager **108** copies the changed data between T_0 and T_1, shown as units **620** and **622**, to the repository **110** to update the full copy $\mathbf{620}_1$ to have data as of T_1. Further, the completed, or frozen, PiT copy information $\mathbf{200}_0$ at T_0 having the changed data $\mathbf{208}_0$ as of T_0, before being updated, is copied to the repository **110** to store as repository PiT copy $\mathbf{608}_0$.

FIG. **6***c* shows a time T_2 when a third PiT copy at T_2 $\mathbf{200}_2$ is created, which may result in the completion or freezing of the PiT copy $\mathbf{200}_1$ at T_1 having changed data $\mathbf{208}_1$ as of the point-in-time T_1 before changes occurring between T_1 and T_2. The repository copy manager **108** copies the changed data between T_1 and T_2, shown as **624** and **626**, to the repository **110** to update the full copy $\mathbf{620}_2$ to have data as of T_2. Further, the completed, or frozen, PiT copy information $\mathbf{200}_1$ at T_1 having the changed data $\mathbf{208}_1$, as of T_1 before being updated, is copied to the repository **110** to store as repository PiT copy $\mathbf{608}_1$.

FIGS. **7***a*, **7***b*, and **7***c* illustrate an example of operations to generate a restore copy **124** at different restore times T_2, T_1, and T_0, respectively, according to the operations of FIG. **5**. FIG. **7***a* shows the repository as of time T_2 being used to create a restore copy $\mathbf{724}_2$ at T_2. As shown in FIG. **7***a*, since the restore time T_2 is equal to the current time of data at the full copy $\mathbf{720}_2$, once the restore copy $\mathbf{724}_2$ is created by copying, either directly or using a point-in-time copy with a background copy, the restore is complete because no rolling back data to a previous restore time is needed because the restore time and the current time are the same, T_2.

FIG. **7***b* illustrates an example of operations to generate a restore copy $\mathbf{724}_1$ as of a restore time of T_i, which is prior in time to the current time T_2 of the repository full copy $\mathbf{620}_2$. To return the restore copy to T_1, the repository copy manager **108** copies the changed data from the repository PiT copy $\mathbf{608}_1$ for the point-in-time of T_1, which has data as of T_1 that has changed between T_1 and T_2.

FIG. **7***c* illustrates an example of operations to generate a restore copy $\mathbf{724}_0$ as of a restore time of T_0, which is prior in time to the current time T_2 of the repository full copy $\mathbf{620}_2$. To return the restore copy to T_0, the repository copy manager **108** copies the changed data from the repository PiT copies $\mathbf{608}_0$ and $\mathbf{608}_1$ for the point-in-times of T_0 and T_1, respectively, which has data as of T_0 that has changed between T_0 and T_2.

FIGS. **8** and **9** illustrate an alternative embodiment where the changed PiT data **208** is not applied to the full copy **110** as done in block **412** of FIG. **4**. Instead, in this alternative embodiment, the full copy **120** remains it its initial state following the first PiT copy at T_0. Blocks **800**, **802**, **804**, **806**, **808**, **810**, **812**, **818**, and **820** of FIG. **8** comprise the operations of blocks **400**, **402**, **404**, **406**, **408**, **410**, **412**, **418**, and **420** in FIG. **4**, except that the full copy remains at its initial state including only data from the first PiT copy $\mathbf{608}_0$.

FIG. **9** provides an alternative embodiment to FIG. **5** to restore the data as of a restore time T_R in the alternative embodiment where the full copy **120** is not updated with the changed data but remains in the state as of the first PiT copy at T_0. Blocks **900**, **902**, **904**, and **912** comprise the operations of blocks **500**, **502**, **504**, and **512** in FIG. **5**, whereas blocks **906**, **908**, and **910** in FIG. **9** differ from blocks **506**, **508**, and **510** in FIG. **5** as follows. If (at block **904**) the restore time T_R is at a point-in-time greater than the current time T_0 of the full copy **120**, then control proceeds to block **906** to roll forward the restore copy **124** created from the full copy **120** at the initial time T_0 to the later restore time T_R. At block **906**, the repository copy manager **108** determines changed PiT data **208** from the change information **206** for each of the PiT copies $\mathbf{200}_i$ having a point-in-time less than or equal to the restore time T_R. A determination is then made (at block **908**) from the determined changed point-in-time data of a most recent of the changed point-in-time data in the repository **110**, i.e., the changed point-in-time data closest in time to the restore time, for PiT copies **200***b* prior the restore point-in-time T_R. The determined most recent of the changed PiT data is copied (at block **910**) to the restore copy **124** to roll the restore copy **124** forward to the time of the restore time T_R. The repository copy manager **108** allows (at block **912**) access to the restore copy **124** in response to copying the changed point-in-time data as of the restore time (T_R) to the restore copy **124** and before the background operation to copy the full copy to the restore copy has completed. If the user attempts to access data in the restore copy **124** not yet copied from the full copy **120**, then the requested data may be retrieved from the full copy **120** to copy to the restore copy **124** and returned to the user.

As with the embodiment of FIG. **5**, in the embodiment of FIG. **9**, the repository copy manager **108** may consolidate the changed data in the PiT copies up to the restore time T_R so that if there are multiple instances of changed data for one data unit at different point-in-times prior to the restore time T_R then only the most recent of the changed data for the data unit from the PiT copies up until the restore time T_R is copied to the restore copy **124**. In an alternative embodiment, the repository copy manager **108** may perform a brute force copy method by starting from the earliest PiT copy prior to the restore time T_R and copying the changed data, and then copying the changed data for each subsequently more recent PiT copy until the changed data for the PiT copy having a point-in-time at the restore time T_R is copied to the restore copy **124**. Other techniques may be used to roll forward the restore copy **120** to the restore time following the current time.

In a still further embodiment, the full copy **120** may be maintained at a point-in-time between the initial point-in-time T_0 and the current point-in-time T_C of the most recent PiT copy. In such case, the restore operation may involve rolling forward or rolling back the full copy **120** from PiT copies before or after the restore time, respectively.

FIG. **10** illustrates an embodiment of operations performed by the repository copy manager **108** to merge instances of repository PiT copy information $\mathbf{200}_i$, also referred to as PiT copies, to consolidate two or more consecutive PiT copies ($PiT_i \ldots PiT_n$) into a single merged PiT copy. FIG. **10** provides operations performed by the repository copy manager **108** for merging PiT copies in the situation where the full copy **120** is continually provided modified data to be current as of the last PiT copy created, such as described with respect to FIGS. **4** and **5**. In this embodiment, at block **414** in FIG. **4**, the full copy **120** is updated with the data that has changed since the previous point-in-time to make the full copy current as of a subsequent point-in-time. In such an embodiment, the PiT copies **200***b* are used to roll back the full copy **120** to a previous point-in-time. Upon receiving (at block **1000**) two or more selected PiT copies 200_i . . . 200_n to merge, the repository copy manager **108** sets (at block **1002**) the PiT **204** for the merged PiT copy to the earliest PiT **204** of the selected PiT copies 200_i . . . 200_n.

The repository copy manager **108** performs a loop of operations at blocks **1004** through **1016** for each data block in the change information **206**, e.g., bitmap, where the bitmap **206** may be initialized to indicate no changed data for any data block. If (at block **1006**) any of the selected consecutive PiT copies to merge has changed data for block j, then the merged change information **206** (bitmap) is set (at block **1008**) to indicate that the merged PiT copy provides changed data for data block j. If (at block **1010**) more than one selected PiT copy provides changed data for data block j, then the repository copy manager **108** sets (at block **1012**) the changed data for data block j to the changed data for earliest PiT copy providing changed data for data block j. If (at block **1010**) only one selected PiT copy provides change data for data block j, then the repository copy manager **108** sets (at block **1014**) the changed data for data block j to the changed data for the one PiT copy providing data for block j. At block **1016**, control proceeds back to block **1002** until all blocks indicated in the change information **206** are considered. The generated merged PiT copy is stored (at block **1018**) in the repository **110** and the selected PiT copies 200_i . . . 200_n subject to the merge may be removed from the repository **110** after forming the merged PiT copy in the repository **110**.

In the embodiment of FIG. **10**, if multiple of the selected PiT copies to merge provide changed data **208** for a data block (at block **1012**), then the data block in the merged changed data **208** is set to the changed data from the earliest PiT copy providing changed data for the data block to allow the full copy **120** to be rolled back to the PiT of the merged selected PiT copies 200_i . . . 200_n, which is the earliest point-in-time **204** of the PiT copies 200_i . . . 200_n being merged.

In an alternative embodiment where the full copy **120** is not updated, but includes data as of the initial PiT copy (T_0), such as described with respect to FIGS. **8** and **9**, the operations in FIG. **10** would be modified such that at block **1002**, the PiT **204** of the merged PiT copy 200_i is set to the most current point-in-time **204** of the selected PiT copies 200_i . . . 200_n or T_n. Further, the operation at block **1012** would be modified to set the changed data block j to the changed data **208** from the most current merged PiT copy 200_i . . . 200_n providing changed data for the data block j to allow the full copy **120** to be rolled forward to the PiT of the merged selected PiT copies i . . . n, which is the most recent point-in-time **204** (T_n) of the PiT copies being merged.

The operations of FIG. **10** for both embodiments consolidates PiT copy information **200***b* in the repository **110** to provide a more efficient storage of PiT copies when certain intermediary PiT copies are no longer needed. Further, the consolidation operation of FIG. **10** conserves space in the repository **110** because if multiple PiT copies provide changed data for the same data blocks, merging these PiT copies reduces the amount of instances of changed data **20** in the repository **110** as well as the data needed to store the change information **206** bitmaps. This frees up space in the repository **110** for newer PiT copies.

Further, the PiT copies may be systematically merged to reduce management overhead by keeping limited PiT copies for a time period. For instance, if there are multiple PiT copies for sub-time periods of a greater time period, e.g., hourly PiT copies for a day, daily PiT copies for a week, weekly PiT copies for a month, etc., then multiple of the sub-time period PiT copies can be merged into one sub-time period PiT copy for the overall time period, e.g., only keep one hour PiT copy for a first day, one day for a first week, and so on.

The described embodiments provide techniques to merge PiT copies in a repository generated by a storage controller **100** that includes a full copy **120** of the source data current and has PiT copy information for PiT copies created by the storage controller **100** at different point-in-times that may be used to restore the source data **104** to a restore copy having the data as of the different point-in-times of the PiT copies maintained at the repository. In a first embodiment, the full copy may be continually updated with changed data maintained with the PiT copies to keep the PiT copy current as of the most recent PiT copy point-in-time. In this first embodiment, the merge operation uses as the merge point-in-time the earliest of the PiT copies being merged. In such case, if multiple of the PiT copies being merged provides changed data for one data block, then the changed data from the PiT copy that has the earliest point-in-time is used in the merged changed data to allow restoration to the point-in-time of the merged PiT copy, which is the earliest point-in-time of the PiT copies being merged.

In a second embodiment, the full copy may not be updated and instead maintained at the initial time T_0 of the first PiT copy. In this second embodiment, the merge operation uses as the merge point-in-time the most recent of the PiT copies being merged. In such case, if multiple of the PiT copies being merged provides changed data for one data block, then the changed data from the PiT copy having the most recent point-in-time is used in the merged changed data to allow restoration to the point-in-time of the merged PiT copy, which is the most recent point-in-time of the PiT copies being merged.

The reference characters used herein, such as i, j, k, l, m, n, are used herein to denote a variable number of instances of an element, which may represent the same or different values, and may represent the same or different value when used with different or the same elements in different described instances.

In certain embodiments, the repository creation and restore operations may be performed by a program component, such as the repository copy manager **108**, that is separate from the storage controller logic, e.g., the PiT copy manager **116** that created the PiT copies.

The present invention may be a system, a method, and/or a computer program product. The computer program product may include a computer readable storage medium (or media) having computer readable program instructions thereon for causing a processor to carry out aspects of the present invention.

The computer readable storage medium can be a tangible device that can retain and store instructions for use by an instruction execution device. The computer readable storage medium may be, for example, but is not limited to, an electronic storage device, a magnetic storage device, an optical storage device, an electromagnetic storage device, a semiconductor storage device, or any suitable combination of the foregoing. A non-exhaustive list of more specific examples of the computer readable storage medium includes the following: a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a static random access memory (SRAM), a portable compact disc read-only memory (CD-ROM), a digital versatile disk (DVD), a memory stick, a floppy disk, a mechanically encoded device such as punchcards or raised structures in a groove having instructions recorded thereon, and any suitable combination of the foregoing. A computer readable storage medium, as used herein, is not to be construed as being transitory signals per se, such as radio waves or other freely propagating electromagnetic waves, electromagnetic waves propagating through a waveguide or other transmission media (e.g., light pulses passing through a fiber-optic cable), or electrical signals transmitted through a wire.

Computer readable program instructions described herein can be downloaded to respective computing/processing devices from a computer readable storage medium or to an external computer or external storage device via a network, for example, the Internet, a local area network, a wide area network and/or a wireless network. The network may comprise copper transmission cables, optical transmission fibers, wireless transmission, routers, firewalls, switches, gateway computers and/or edge servers. A network adapter card or network interface in each computing/processing device receives computer readable program instructions from the network and forwards the computer readable program instructions for storage in a computer readable storage medium within the respective computing/processing device.

Computer readable program instructions for carrying out operations of the present invention may be assembler instructions, instruction-set-architecture (ISA) instructions, machine instructions, machine dependent instructions, microcode, firmware instructions, state-setting data, or either source code or object code written in any combination of one or more programming languages, including an object oriented programming language such as Java, Smalltalk, C++ or the like, and conventional procedural programming languages, such as the "C" programming language or similar programming languages. The computer readable program instructions may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider). In some embodiments, electronic circuitry including, for example, programmable logic circuitry, field-programmable gate arrays (FPGA), or programmable logic arrays (PLA) may execute the computer readable program instructions by utilizing state information of the computer readable program instructions to personalize the electronic circuitry, in order to perform aspects of the present invention.

Aspects of the present invention are described herein with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems), and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer readable program instructions.

These computer readable program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks. These computer readable program instructions may also be stored in a computer readable storage medium that can direct a computer, a programmable data processing apparatus, and/or other devices to function in a particular manner, such that the computer readable storage medium having instructions stored therein comprises an article of manufacture including instructions which implement aspects of the function/act specified in the flowchart and/or block diagram block or blocks.

The computer readable program instructions may also be loaded onto a computer, other programmable data processing apparatus, or other device to cause a series of operational steps to be performed on the computer, other programmable apparatus or other device to produce a computer implemented process, such that the instructions which execute on the computer, other programmable apparatus, or other device implement the functions/acts specified in the flowchart and/or block diagram block or blocks.

The flowchart and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer program products according to various embodiments of the present invention. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of instructions, which comprises one or more executable instructions for implementing the specified logical function(s). In some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts or carry out combinations of special purpose hardware and computer instructions.

The computational components of FIG. **1**, including the storage controller **100** and host **106** may be implemented in one or more computer systems, such as the computer system **1102** shown in FIG. **11**. Computer system/server **1102** may be described in the general context of computer system executable instructions, such as program modules, being executed by a computer system. Generally, program modules may include routines, programs, objects, components, logic, data structures, and so on that perform particular tasks or implement particular abstract data types. Computer system/server **1102** may be practiced in distributed cloud computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed cloud computing environment, program modules may be located in both local and remote computer system storage media including memory storage devices.

As shown in FIG. **11**, the computer system/server **1102** is shown in the form of a general-purpose computing device. The components of computer system/server **1102** may include, but are not limited to, one or more processors or processing units **1104**, a system memory **1106**, and a bus **1108** that couples various system components including system memory **1106** to processor **1104**. Bus **1108** represents one or more of any of several types of bus structures, including a memory bus or memory controller, a peripheral bus, an accelerated graphics port, and a processor or local bus using any of a variety of bus architectures. By way of example, and not limitation, such architectures include

Industry Standard Architecture (ISA) bus, Micro Channel Architecture (MCA) bus, Enhanced ISA (EISA) bus, Video Electronics Standards Association (VESA) local bus, and Peripheral Component Interconnects (PCI) bus.

Computer system/server **1102** typically includes a variety of computer system readable media. Such media may be any available media that is accessible by computer system/server **1102**, and it includes both volatile and non-volatile media, removable and non-removable media.

System memory **1106** can include computer system readable media in the form of volatile memory, such as random access memory (RAM) **1110** and/or cache memory **1112**. Computer system/server **1102** may further include other removable/non-removable, volatile/non-volatile computer system storage media. By way of example only, storage system **1113** can be provided for reading from and writing to a non-removable, non-volatile magnetic media (not shown and typically called a "hard drive"). Although not shown, a magnetic disk drive for reading from and writing to a removable, non-volatile magnetic disk (e.g., a "floppy disk"), and an optical disk drive for reading from or writing to a removable, non-volatile optical disk such as a CD-ROM, DVD-ROM or other optical media can be provided. In such instances, each can be connected to bus **1108** by one or more data media interfaces. As will be further depicted and described below, memory **1106** may include at least one program product having a set (e.g., at least one) of program modules that are configured to carry out the functions of embodiments of the invention.

Program/utility **1114**, having a set (at least one) of program modules **1116**, may be stored in memory **1106** by way of example, and not limitation, as well as an operating system, one or more application programs, other program modules, and program data. Each of the operating system, one or more application programs, other program modules, and program data or some combination thereof, may include an implementation of a networking environment. The components of the computer **1102** may be implemented as program modules **1116** which generally carry out the functions and/or methodologies of embodiments of the invention as described herein. The systems of FIG. **1** may be implemented in one or more computer systems **1102**, where if they are implemented in multiple computer systems **1102**, then the computer systems may communicate over a network.

Computer system/server **1102** may also communicate with one or more external devices **1118** such as a keyboard, a pointing device, a display **1120**, etc.; one or more devices that enable a user to interact with computer system/server **1102**; and/or any devices (e.g., network card, modem, etc.) that enable computer system/server **1102** to communicate with one or more other computing devices. Such communication can occur via Input/Output (I/O) interfaces **1122**. Still yet, computer system/server **1102** can communicate with one or more networks such as a local area network (LAN), a general wide area network (WAN), and/or a public network (e.g., the Internet) via network adapter **1124**. As depicted, network adapter **1124** communicates with the other components of computer system/server **1102** via bus **1108**. It should be understood that although not shown, other hardware and/or software components could be used in conjunction with computer system/server **1102**. Examples, include, but are not limited to: microcode, device drivers, redundant processing units, external disk drive arrays, RAID systems, tape drives, and data archival storage systems, etc.

The terms "an embodiment", "embodiment", "embodiments", "the embodiment", "the embodiments", "one or more embodiments", "some embodiments", and "one embodiment" mean "one or more (but not all) embodiments of the present invention(s)" unless expressly specified otherwise.

The terms "including", "comprising", "having" and variations thereof mean "including but not limited to", unless expressly specified otherwise.

The enumerated listing of items does not imply that any or all of the items are mutually exclusive, unless expressly specified otherwise.

The terms "a", "an" and "the" mean "one or more", unless expressly specified otherwise.

Devices that are in communication with each other need not be in continuous communication with each other, unless expressly specified otherwise. In addition, devices that are in communication with each other may communicate directly or indirectly through one or more intermediaries.

A description of an embodiment with several components in communication with each other does not imply that all such components are required. On the contrary a variety of optional components are described to illustrate the wide variety of possible embodiments of the present invention.

When a single device or article is described herein, it will be readily apparent that more than one device/article (whether or not they cooperate) may be used in place of a single device/article. Similarly, where more than one device or article is described herein (whether or not they cooperate), it will be readily apparent that a single device/article may be used in place of the more than one device or article or a different number of devices/articles may be used instead of the shown number of devices or programs. The functionality and/or the features of a device may be alternatively embodied by one or more other devices which are not explicitly described as having such functionality/features. Thus, other embodiments of the present invention need not include the device itself.

The foregoing description of various embodiments of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is intended that the scope of the invention be limited not by this detailed description, but rather by the claims appended hereto. The above specification, examples and data provide a complete description of the manufacture and use of the composition of the invention. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims herein after appended.

What is claimed is:

1. A method for maintaining source data in a repository, the method comprising:

maintaining in the repository a full copy of the source data and point-in-time copies at different point-in-times of the source data, wherein each of the point-in-time copies have change information indicating changed data in the source data that changed between a point-in-time of a point-in-time copy and a subsequent point-in-time and wherein each of the point-in-time copies further have changed data comprising data in the source data as of the point-in-time of the point-in-time copy indicated in the change information as changed, wherein the full copy includes data as of a most recent point-in-time of the point-in-time copies, and wherein the point-in-time copies are used to restore the full copy to a point-in-time prior to the point-in-time of the full copy; and merging selected point-in-time copies of the point-in-time copies in the repository into a merged point-in-time copy in the repository, by:

setting a merged point-in-time for the merged point-in-time copy to an earliest point-in-time of the selected point-in-time copies;

forming merged change information in the merged point-in-time copy indicating changed data indicated in change information for the selected point-in-time copies; and

forming merged changed data in the merged point-in-time copy for each data block by:

determining at least one of the selected point-in-time copies providing changed data for the data block;

including the changed data from one determined selected point-in-time copy having the merged point-in-time when only one of the selected point-in-time copies provides changed data for the data block; and

including changed data from a selected point-in-time copy having the earliest point-in-time of the selected point-in-time copies when multiple of the selected point-in-time copies provides changed data for the data block;

storing the merged point-in-time copy in the repository, resulting from the merging of the selected point-in-time copies, including the merged point-in-time, the merged change information, and the merged changed data to consolidate point-in-time copy information from the selected point-in-time copies in the merged point-in time copy; and

using the merged point-in-time copy to restore the source data to a point-in-time of the merged point-in-time copy.

2. The method of claim **1**, wherein the using the merged point-in-time copy to restore the source data further comprises:

applying the merged changed data to a restore copy to make the restore copy consistent as of a point-in-time of one of the selected point-in-time copies to merge.

3. The method of claim **1**, wherein one of the point-in-time copies is completed in response to at least one of freezing a point-in-time copy or creating a subsequent point-in-time copy.

4. The method of claim **1**, wherein the point-in-time copies and merged point-in-time copy are generated by a point-in-time copy program and wherein a repository copy program executed separately from the point-in-time copy program performs the merging the selected point-in-time copies.

5. The method of claim **1**, wherein the forming the merged change information comprises indicating in the merged change information that data blocks have changed data when the change information for one of the selected point-in-time copies indicates that those data blocks have changed data.

6. The method of claim **1**, further comprising:

removing the selected point-in-time copies involved in the merging from the repository in response to forming the merged point-in-time copy in the repository.

7. The method of claim **1**, further comprising:

in response to completing each of the point-in-time copies, transmitting to the full copy the source data at the subsequent point-in-time to make the full copy current as of the subsequent point-in-time.

8. A system for maintaining source data in a repository, comprising:

a processor; and

a computer readable storage medium including computer program code that when executed by the processor performs operations, the operations comprising:

maintaining in the repository a full copy of the source data and point-in-time copies at different point-in-times of the source data, wherein each of the point-in-time copies have change information indicating changed data in the source data that changed between a point-in-time of a point-in-time copy and a subsequent and wherein each of the point-in-time copies further have changed point in time data comprising data in the source data as of the point-in-time of the point-in-time copy indicated in the change information as changed, wherein the full copy includes data as of a most recent point-in-time of the point-in-time copies, and wherein the point-in-time copies are used to restore the full copy to a point-in-time prior to the point-in-time of the full copy; and

merging selected point-in-time copies of the point-in-time copies in the repository into a merged point-in-time copy in the repository, by:

setting a merged point-in-time for the merged point-in-time copy to an earliest point-in-time of the selected point-in-time copies;

forming merged change information in the merged point-in-time copy indicating changed data indicated in change information for the selected point-in-time copies; and

forming merged changed data in the merged point-in-time copy for each data block by:

determining at least one of the selected point-in-time copies providing changed data for the data block;

including the changed data from one determined selected point-in-time copy t when only one of the selected point-in-time copies provides changed data for the data block; and

including changed data from a selected point-in-time copy having the earliest point-in-time of the selected point-in-time copies when multiple of the selected point-in-time copies provides changed data for the data block;

storing the merged point-in-time copy in the repository resulting from the merging of the selected point-in-time copies including the merged point-in-time, the merged change information, and the merged changed data to consolidate point-in-time copy information from the selected point-in-time copies in the merged point-in time copy; and

using the merged point-in-time copy to restore the source data to a point-in-time of the merged point-in-time copy.

9. The system of claim **8**, wherein the using the merged point-in-time copy to restore the source data further comprises:

applying the merged changed data to a restore copy to make the restore copy consistent as of a point-in-time of one of the selected point-in-time copies to merge.

10. The system of claim **8**, wherein one of the point-in-time copies is completed in response to at least one of freezing a point-in-time copy or creating a subsequent point-in-time copy.

11. The system of claim **8**, wherein the point-in-time copies and merged point-in-time copy are generated by a point-in-time copy program and wherein a repository copy program executed separately from the point-in-time copy program performs the merging the selected point-in-time copies.

12. The system of claim **8**, wherein the forming the merged change information comprises indicating in the merged change information that data blocks have changed data when the change information for one of the selected point-in-time copies indicates that those data blocks have changed data.

13. The system of claim **8**, further comprising:

removing the selected point-in-time copies involved in the merging from the repository in response to forming the merged point-in-time copy in the repository.

14. The system of claim **8**, further comprising:

in response to completing each of the point-in-time copies, transmitting to the full copy the source data at the subsequent point-in-time to make the full copy current as of the subsequent point-in-time.

15. A computer program product for maintaining source data in a repository, the computer program product comprising:

a computer readable storage medium readable by a processing circuit and storing instructions for execution by the processing circuit for performing a method, the method comprising:

maintaining in the repository a full copy of the source data and point-in-time copies at different point-in-times of the source data, wherein each of the point-in-time copies have change information indicating changed data in the source data that changed between a point-in-time of a point-in-time copy and a subsequent point-in-time and wherein each of the point-in-time copies further have changed data comprising data in the source data as of the point-in-time of the point-in-time copy indicated in the change information as changed, wherein the full copy includes data as of a most recent point-in-time of the point-in-time copies, and wherein the point-in-time copies are used to restore the full copy to a point-in-time prior to the point-in-time of the full copy; and

merging selected point-in-time copies of the point-in-time copies in the repository into a merged point-in-time copy in the repository, by:

setting a merged point-in-time for the merged point-in-time copy to an earliest point-in-time of the selected point-in-time copies;

forming merged change information in the merged point-in-time copy indicating changed data indicated in change information for the selected point-in-time copies; and

forming merged changed data in the merged point-in-time copy for each data block by:

determining in at least one of the selected point-in-time copies;

including the changed data from one determined selected point-in-time copy t when only one of the selected point-in-time copies provides changed data for the data block; and

including changed data from a selected point-in-time copy having the earliest point-in-time of the selected point-in-time copies when multiple of the selected point-in-time copies provides changed data for the data block;

storing the merged point-in-time copy in the repository resulting from the merging of the selected point-in-time copies including the merged point-in-time, the merged change information and the merged changed data to consolidate point-in-time copy information from the selected point-in-time copies in the merged point-in time copy; and

using the merged point-in-time copy to restore the source data to a point-in-time of the merged point-in-time copy.

16. The computer program product of claim **15**, wherein the using the merged point-in-time copy to restore the source data further comprises:

applying the merged changed data to a restore copy to make the restore copy consistent as of a point-in-time of one of the selected point-in-time copies to merge.

17. The computer program product of claim **15**, further comprising:

removing the selected point-in-time copies involved in the merging from the repository in response to forming the merged point-in-time copy in the repository.

18. The method of claim **1**, wherein the merged point-in-time copy is separate from the selected point-in-time copies subject to the merging in the repository.

19. The system of claim **8**, wherein the merged point-in-time copy is separate from the selected point in time copies subject to the merging in the repository.

20. The computer program product of claim **15**, wherein the merged point-in-time copy is separate from the selected point in time copies subject to the merging in the repository.

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